THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION
Colleges of Agricultural and Environmental Sciences & Family and Consumer Sciences

Commercial Pepper Production Handbook

Foreword

This publication is a joint effort of the seven disciplines that comprise the Georgia Vegetable Team. It is comprised of 14 topics on pepper, including history of pepper production, cultural practices, pest management, harvesting, handling and marketing. The publication provides information that will help producers improve the profitability of pepper production, whether they are new or experienced producers.

Peppers are an important crop for Georgia growers, but successful pepper production is not easily achieved. Pepper production requires highly intensive management, production and marketing skills, and a significant investment. Per-acre cost of production is high, and yields can be severely limited by pest problems or environment. Pepper production is complex. Expertise in the areas of cultural practices, soils and fertility management, pest control, harvesting, post-harvest handling, marketing, and farm record keeping is crucial to profitable production.

In writing this publication, the authors have strived to provide a thorough overview of all aspects of pepper production. Chemical pest control recommendations are not included, however, as these change from year to year. For up-to-date chemical recommendations, see the current *Georgia Pest Management Handbook,* or check with your county extension office.

Contents

Pepper History, Scope, Climate and Taxonomy

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Pepper (*Capsicum* sp.) is one of the most varied and widely used foods in the world. From the various colors to the various tastes, peppers are an important spice commodity and an integral part of many cuisines. Peppers originated in the Mexico and Central America regions. Christopher Columbus encountered pepper in 1493 and, because of its pungent fruit, thought it was related to black pepper, *Piper nigrum*, which is actually a different genus. Nevertheless, the name stuck and he introduced the crop to Europe, and it was subsequently spread into Africa and Asia.

Peppers were important to the earliest inhabitants of the western hemisphere as much as 10,000 to 12,000 years ago. Plant remnants have been found in caves in the region of origin that date back to 7,000 B.C. The Incas, Aztec and Mayans all used pepper extensively and held the plant in high regard. Many of the early uses of pepper centered around medicinal purposes. Pepper has been credited with any number of useful cures and treatments, some of which are valid and some of which are probably more folklore.

Virtually every country in the world produces pepper. The bulk of pepper produced in the United States is sweet pepper, but hot peppers dominate in other countries. Globally, pepper production exceeds 14 million metric tons. California is the leading producer of sweet peppers in the United States. Fresh market production is a large part of the U.S. market, although processed peppers are common in all parts of the world as dried, pickled or otherwise processed products.

Pepper production has increased in recent years worldwide. That could be at least in part because of the high nutritional value of pepper. One medium green bell pepper can provide up to 8 percent of the Recommended Daily Allowance of Vitamin A, 180 percent of Vitamin C, 2 percent of calcium and 2 percent of iron. Additionally pepper contains significant amounts of A and the B vitamins.

All peppers are members of the *Solanacea* family, which also includes tomato, tobacco, eggplant and Irish potato. There has been much debate over the years as to how many species of Capsicum truly exist. The number has fluctuated over the centuries from 1 to 90. Currently five species are recognized as domesticated. Among these are *C. annum,* which includes the bulk of cultivated types including bell, yellow wax, cherry, ancho, cayenne, jalapeno and serrano. *C. chinense* includes the habaneros and Scotch bonnet. Tobasco is the most notable variety in the *C. frutescens* species. The only important variety in the *C. battacum* species is the Yellow Peruvian Pepper. *C. pubescens* includes 'manzano' and 'peron' pod types. The classification of species will obviously continue to evolve in the future. There are an additional 20 or more species of wild types.

A phenolic compound called capsaicin is responsible for the pungency in peppers. The compound is related to vanillin. It is not located in all parts of the fruit, and various cultivars differ markedly in their content of this chemical. Pepper is considered a self-pollinating crop although some out crossing will occur. Although grown as an annual crop due to its sensitivity to frost, pepper is actually a herbaceous perennial and will survive and yield for several years in tropical climates.

Peppers grow well in warm climates with a relatively long growing season. Most cultivated peppers require around 75 days from transplanting to first harvest and can be harvested for several weeks before production wanes. Ideal temperatures for pepper growth are in the range of 75-89 degrees F during the day and 65-75 degrees F at night. Significantly higher or lower temperatures can have negative effects on fruit set and quality.

Cultural Practices and Varieties

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Soil Requirements and Site Preparation

Peppers can be produced on a wide variety of soil types. They grow best, however, in deep, medium textured sandy loam or loamy, fertile, well-drained soils. Avoid sites that tend to stay wet. Also, rotate away from fields that have had solanaceous crops within the past 3 or 4 years.

In field production, plants depend on the soil for (1) physical support and anchorage, (2) nutrients and (3) water. The degree to which the soil adequately provides these three factors depends upon topography, soil type, soil structure and soil management.

For pepper production, proper tillage is crucial for adequate soil management and optimal yields. Land preparation should involve enough tillage operations to make the soil suitable for seedling (or transplant) establishment and to provide the best soil structure for root growth and development.

The extent to which the root systems of pepper plants develop is influenced by the soil profile. Root growth will be restricted if there is a hard pan, compacted layer or heavy clay zone. Peppers are considered to be moderately deep rooted and, under favorable conditions, roots will grow to a depth of 36 to 48 inches. But the majority of roots will be in the upper 12 to 24 inches of soil. Since root development is severely limited by compacted soil, proper land preparation should eliminate or significantly reduce soil compaction and hard pans.

Tillage systems using the moldboard ("bottom") plow prepare the greatest soil volume conducive to vigorous root growth. This allows more extensive root systems to develop, which can more efficiently access nutrients and water in the soil. Discing after moldboard plowing tends to re-compact the soil and should be avoided.

Compaction pans are present in many soils. They are formed principally by machinery and, when present, are normally located at or just below plow depths. Even though compaction pans may be only a few inches thick, their inhibitory effects on root growth can significantly reduce pepper yields.

If a compaction pan exists just below or near moldboard plow depth, this hard pan can be disrupted by subsoiling to a depth of 16 to 18 inches to allow the development of a more extensive root system. Subsoiling also helps increase water infiltration.

If there is an abundance of plants or plant residues on the soil surface, discing or mowing followed by discing is usually advised prior to moldboard plowing. Immediately prior to mulch installation or transplanting, do final soil preparation and/or bedding with a rotary tiller, bedding disc or a double disc hiller in combination with a bedding press or leveling board. This provides a crustless, weed free soil for the installation of plastic mulch or the establishment of transplants.

Peppers are usually transplanted into plastic mulch on raised beds. A raised bed will warm up more quickly in the spring and therefore may enhance earlier growth. Since peppers do poorly in excessively wet soils, a raised bed improves drainage and helps prevent water logging in low areas or poorly drained soils. Raised beds are generally 3 to 8 inches high. Keep in mind, however, that peppers planted on raised beds may also require more irrigation during drought conditions.

Cover Crops and Minimum Tillage

Winter cover crops help protect the soil from water and wind erosion. When incorporated into the soil as "green manure," cover crops contribute organic matter to the soil.

Soil organic matter consists of plant and animal residues in various stages of decay. Organic matter (1) improves soil structure (helps reduce compaction and crusting), (2) increases water infiltration, (3) decreases water and wind erosion, (4) increases the soil's ability to resist leaching of many plant nutrients, and (5) releases plant nutrients during decomposition.

Planting cover crops and the subsequent incorporation of the green manure into the soil enhances pepper production in Coastal Plains soils. Use wheat, oats, rye or ryegrass as winter cover crops. If these non-nitrogen fixing cover crops are to be incorporated as green manure, provide them with adequate nitrogen during their growth. This increases the quantity of organic matter produced and provides a carbon: nitrogen (C:N) ratio less likely to immobilize nitrogen during decomposition.

As a general rule, when non-leguminous organic matter having a C:N ratio exceeding 30 to 1 is incorporated, a supplemental nitrogen application (usually 20 to 30 pounds of nitrogen per acre) prior to incorporation is recommended. The exact rate required will depend on the C:N ratio, soil type and amount of any residual nitrogen in the soil. Plow green manure crops under as deeply as possible with a moldboard plow at least two weeks prior to installing mulch or transplanting peppers.

Planting peppers in reduced tillage situations has been tried with modest success. Often these cover crops can be killed with a burn down herbicide. Then pepper is either transplanted directly into the cover or a narrow strip is tilled and prepared for transplanting while leaving the residue between rows.

The primary encumbrance to success in these systems is adequate weed and disease control. Because of this, reduced tillage is used only on a limited basis in commercial pepper production. With advances in weed and disease control technology, this type of production may become more feasible in the future.

Windbreaks

Crop windbreaks can act as a crop protection aid. Frequency or intervals between windbreaks is dictated by distance between pepper rows, spray or harvest alleyway intervals, land availability and equipment characteristics. For instance, bed arrangements may be such that a windbreak is present between every set of four, six or eight beds.

In general, close windbreaks give the best wind protection and help moderate the pepper plants' microenvironment and enhance earliness. Especially on sandy soils, windbreaks reduce damage from sand-blasting of plants and small fruit during early spring. Sandblasting can be more of a problem with plastic mulch since the soil particles are carried easily by the wind across the field.

Regardless of the species selected as a windbreak, it should be planted early enough to be effective as a windbreak by the time peppers are transplanted. Establishment of a windbreak crop during the fall or early winter should ensure enough growth for an effective windbreak by spring pepper planting time. Wheat, oats or rye all make good windbreak crops.

Pepper beds can be established between the windbreaks by tilling only in the bed area.

To minimize insect migration to the pepper crop, destroy windbreak crops by herbicides, mowing and/or tillage before they lose their green color and begin to die back.

Transplanting

Seeding pepper directly into the field is not recommended due to the high cost of hybrid seed and the specific conditions required for adequate germination. Most pepper is transplanted to the field from greenhouse-grown plants. Direct seeding has other disadvantages:

1. Weed control is usually much more difficult with direct seeded than with transplanted pepper.
2. Direct seeding requires especially well-made seedbeds and specialized planting equipment to adequately control depth of planting and in-row spacing.
3. Because of the shallow planting depth required for pepper seed, the field must be nearly level to prevent seeds from being washed away or covered too deeply with water transported soil.
4. Spring harvest dates will be at least three to four weeks later for direct seeded pepper. At 59, 68 and 77 degrees F soil temperature, pepper seed require 25, 13 and 8 days, respectively, for emergence.

Typically, 5- to 6-week old pepper seedlings are transplanted into the field. As with most similar vegetable crops, container-grown transplants are preferred over bare root plants. Container grown transplants retain transplant growing medium (soil-substitute) attached to their roots after removal from the container (flat, tray). Many growers prefer this type transplant because (1) they are less subject to transplant shock; (2) they usually require little, if any, replanting; (3) they resume growth more quickly after transplanting; and (4) they grow and produce more uniformly.

Pepper transplants should be hardened off before transplanting in the field. Hardening off is a technique used to slow plant growth prior to field setting so the plant can more successfully transition to the less favorable conditions in the field. This process involves decreasing water, nutrients and temperature for a short period prior to taking the plants to the field.

For maximum production, transplants should never have fruits, flowers or flower buds before transplanting. An ideal transplant is young (6 to 8 inches tall with a stem approximately ⅜ inch to ¼ inch in diameter), does not exhibit rapid vegetative growth, and is slightly hardened at transplanting time. Rapid growth following transplanting helps assure a well established plant before fruit develops.

Set transplants as soon as possible after removing from containers or pulling. If it is necessary to hold pepper plants for several days before transplanting, keep them cool (around 55-65 degrees F if possible) and do not allow the roots to dry out prior to transplanting. When setting plants, place roots 3 to 4 inches deep. Setting plants at least as deep as the cotyledons has shown to enhance plant growth and earliness. Completely cover the root ball with soil to prevent wicking moisture from the soil. Peppers grow best if nighttime soil temperatures average more than 60 degrees F.

At transplanting, apply an appropriate fertilizer starter solution (see Fertilizer Management section). After transplanting (especially within the first 2 weeks) maintain soil moisture so plant roots can become well established.

Plant Spacing

Optimal plant population per acre depends upon plant growth habit (compact, medium, spreading), plant size (small, medium, large) at maturity, vigor of specific cultivars, climate, soil moisture, nutrient availability, management system and soil productivity. Adequate populations for the many different types and cultivars of peppers range from approximately 7,500 to 14,500 plants per acre.

Sweet bell pepper types are more compact than many other kinds of pepper and, with traditional plastic mulch production, are usually planted with two rows on each bed with plants spaced 12 inches apart. The beds are usually 60 to 72 inches apart from center to center and the rows on the bed are generally about 14 to 18 inches apart. On bare ground, space rows 36 to 42 inches apart with 12 inches to 16 inches between plants in the row. Normally from 12,000 to 15,000 plants per acre are considered adequate for bell pepper production. For other kinds of peppers, which produce larger type plants, decrease the population accordingly.

Varieties

Select varieties on the basis of marketable yield potential, quality, market acceptability and disease resistance or tolerance. While there are numerous commercially available varieties that will perform well under Georgia conditions, these varieties perform differently under various environmental conditions.

When selecting a variety, yield should not be the only selection criteria. Plants need to produce adequate foliage to protect fruit from sunburn. Market preferences for fruit size and color should also be considered. Disease resistance is more important with diseases for which there are no other good management options. Basically, a variety must be adaptable to the area, produce a competitive yield and be acceptable to buyers.

All commercially important bell peppers grown in Georgia belong to the genus *Capsicum annuum.* Some pungent varieties encompass other species. Table 1 lists varieties that have performed well in Georgia or in similar areas of the southeastern United States. Notations in the disease resistance column indicate either resistance or tolerance. Some varieties may not exhibit complete resistance to the disease listed.

Table 1. Bell pepper varieties that have exhibited acceptable performance either in variety trials or in grower fields in Georgia.

Variety	Days to Maturity	Color	Shape	Disease Resistance
X3R Aladdin	70	Green to Yellow	Large blocky	BLS^{123}, TMV
Alliance	72	Green to Red	Blocky	BLS^{1235}, PHY, CMV, PVY, PMV
X3R Aristotle	72	Green to Red	3-4 Lobed	BLS^{123}, TMV, PVY
Brigadier	71	Green to Red	Large blocky	BLS^{123}, PVY
Camelot X3R	75	Green to Red	Elongated	BLS^{123}, TMV
Commandant	80	Green to Red	Deep blocky	BLS^{123}, TMV, PVY, PMV
Crusader	75	Green to Red	Large blocky	BLS^{123}, TMV, PVY, S, PMV
Excursion II	75	Green to Red	Large blocky	BLS^{123}, TSW, TMV, PVY
Heritage	75	Green to Red	Blocky	BLS^{123}, TSW
King Arthur	68	Green to Red	3-4 Lobed	BLS^{123}, TMV, PVY, TEV
Paladin	72	Green to Red	Deep blocky	PHY, TMV
Patriot	70	Green to Red	Deep blocky	BLS^{123}, PVY
Plato	75	Green to Red	Blocky	BLS^{123}, TSW
X3R Red Knight	63	Green to Red	Large blocky	BLS^{123}, PVY
Revolution		Green to Red	Blocky	BLS^{1235}, CMV, PHY
Sentry	75	Green to Red	Very blocky	BLS^{123}, S
Stiletto	75	Green to Red	Blocky	BLS^{123}, TSW
Summer Sweet 8610	73	Green to Yellow	Deep blocky	BLS^{123}, TMV, PVY
X3R Wizard	75	Green to Red	Deep blocky	BLS^{123}, TMV

BLS = Bacterial Leaf Spot; PHY = Phytothphora capsici; TMV = Tomato Mosaic Virus; PVY = Potato Virus Y; CMV = Cucumber Mosaic Virus; S = Stipling; TEV = Tobacco Etch Virus; PMV = Pepper Mottle Virus

Transplant Production

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Modern production techniques coupled with more costly hybrid seed make pepper transplant production a cost effective alternative to direct seeding. Because of the high cost of production associated with plastic mulch use, staking and drip irrigation, growers can not afford to have a less than perfect stand. This can only be achieved with transplants.

Growers wishing to use transplants but not willing or able to produce transplants themselves need to plan ahead to ensure sufficient plants can be produced in a timely manner to meet their needs. This will mean contracting and coordinating with a transplant grower at least 3-4 months before field planting. If you want to contract with a transplant grower, you need to specify the cell size desired, the variety to be planted, and a specific delivery date. Also, determine whether the transplant grower or the pepper grower will furnish the seed.

Most greenhouse operations use mechanical seeders to plant the seed into the trays or flats. These seeders require that the seed be coated so all seeds are the same size. Coated seed will increase seed costs and any surplus coated seed cannot be returned to the seed company. The cost to the grower for this type transplant will vary depending on the volume ordered and the cell size of the tray.

Containerized plant producers specialize in growing plants in greenhouses designed specifically for the production of transplants. These special houses use plant trays designed to produce the maximum number of transplants per square foot of house space. Plants are usually grown in Styrofoam or plastic trays, and the cell size in these trays determines the number of transplants per tray and the price per thousand for transplants. In general, the larger cell size will produce a larger plant with a greater stem diameter; producing plants in large cells is more costly, however, because there are fewer plants per square foot.

Producing Transplants

Pepper transplant production is usually done in a protected structure such as a green-house. Other protected structures — plastic row covers and high tunnels — can be used for in-ground or bed production. In-field production is also possible in high-density plantings that are pulled bareroot, bundled, crated and shipped to growers. These types of production are rarely used any longer because of problems with disease and temperature control. Peppers usually command a high enough price to offset the cost of using a heated greenhouse for transplant production. This, of course, is only the case for larger growers and dedicated greenhouse operations; smaller growers will find it economical to contract production.

For peppers, a cell size of 1-1.5 inches is recommended. This will produce a plant of sufficient size for easy handling while efficiently using greenhouse space. This cells size will produce a 4- to 6-inch tall pepper plant at transplanting time. Peppers are relatively slow growing in comparison to many other transplants and a minimum of 5-7 weeks is needed to produce a transplant of sufficient size for easy handling.

Pepper seed will germinate best at a temperature of approximately 80 degrees F. Wide fluctuation in greenhouse temperatures will cause delayed emergence of pepper plants. Bottom heat, approaching 80 degrees F, will greatly enhance uniform emergence of seedlings in about 8 days after seeding. Coated seed may require more days for germination and plant emergence. Direct sunlight in greenhouses that leads to temperatures at 90 degrees F or above can be detrimental to pepper seed germination and growth. Shade cloth of 30-50 percent may help alleviate this problem. This is particularly true during summer transplant production for a fall crop.

Approximately 7 ounces of pepper seed is required to produce 10,000 transplants. This can vary significantly based on variety, seed size for a particular lot, and percent germination. Many seed companies now sell seed by the count. Each seed lot will have been counted, which, when coupled with the percent germination, gives growers a more accurate method for purchasing seed.

Common containers for transplant peppers include Styrofoam, plastic flats and inserts, and rigid plastic trays. The Styrofoam and rigid plastic trays are reusable; the inserts used with the flat and insert system are disposed of. Carefully wash reusable containers from one season to the next to prevent disease spread.

A number of commercial potting mixes are available for use in pepper transplant production. Most of these are peat-based media with various additives to improve texture, wettability, pH and fertility. The finer textured media are best for starting seed and will usually have a higher percentage of vermiculite. These media will generally be uniform from one batch to another and will help eliminate weed and disease related problems. Three cubic feet of potting mix should fill from 16 to 20 flats that have a cell size 1.5 inches x 1.5 inches x 2.25 inches. Three cubic feet of potting mix should produce 1,100 to 1,400 transplants.

Plant pepper seed about 0.25 inch deep. The seed may be coated with a fungicide to help prevent dampening off. This usually will appear as a pink or purple coating on the seed. Be careful if using treated seed. If planting by hand, use rubber gloves. Workers should avoid touching their eyes or mouth when handling treated seed. Newer coating technologies are available that do not come off the seed while still offering disease prevention characteristics. Pelleted seed may also be used, especially if automated seeding equipment is to be used. The pelleting, which comes in various thicknesses, allows equipment to singulate and plant the seed.

Many potting mixes come with some fertilizer already incorporated. This media is often referred to as "being charged." With such media, sufficient nutrients should be present for 3-4 weeks before additional fertilizer will have to be applied. Many growers prefer to use an uncharged media, since this gives them more control over when and how much fertilizer to apply. If you plan to fertilize with every irrigation, 50 ppm of a complete water-soluble, fertilizer should be sufficient. If fertilizer is only going to be applied intermittently (every third or fourth watering), then higher rates up to 200 ppm may be employed. Inexpensive electrical conductivity meters can be used to measure relative fertility. Electrical conductivity of 1.0-2.0 mS usually indicates adequate fertility in peat-based media.

An assessment of plant size may be necessary as the plants near transplanting. Plants will have to be large enough to be handled and transplanted properly, but not so large that they interfere with transplanting equipment or suffer undue stress when transplanted. Plants may require more time to grow if too short, or they may require early hardening off (see below) to slow growth.

Peppers should be hardened off prior to transplanting in the field. This usually involves reducing fertilizer application, watering and greenhouse temperatures. Some greenhouses are designed where the sidewalls can be completely opened, which should be done at this time, at least during the day. Hardening off pepper transplants will take 7-10 days. Avoid over-hardening transplants, which can delay the start of growth in the field and reduce early yields.

It may be necessary to delay planting because the field is inaccessible or because of adverse weather conditions. Under these circumstances, take care that plants are not overly stressed by heat, cold or lack of water. If they are on an enclosed trailer, it may be necessary to unload the plants and ensure adequate moisture.

Pepper Production Using Plastic Mulch

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The use of plastic mulch in the production of peppers is almost universal in the Southeast. Plastic mulch is used to promote earliness, reduce weed pressure, and conserve moisture and fertilizer. Most often drip irrigation is used in conjunction with plastic mulch. There are both advantages and disadvantages to producing crops under this system.

Advantages

Plastic mulch promotes earliness by capturing heat, which increases soil temperatures and accelerates growth. Black plastic will prevent the establishment of many in-row weeds. Mulch will reduce fertilizer leaching from pepper beds and will conserve moisture by reducing soil surface evaporation. Furthermore, where fumigants are used, plastic mulch provides a barrier that increases fumigant efficiency.

Plastic mulch also keeps fruit cleaner by reducing soil spatter. When using drip irrigation, disease is often reduced because the foliage stays drier and soil is, again, not splashed onto the plant. Plastic mulch also decreases incidence of Tomato Spotted Wilt, particularly when UV-reflective mulch is used.

Disadvantages

Specialized equipment is required to lay plastic mulch, which means increased variable costs for custom application or the purchase of this equipment. Yellow and purple nutsedges are not controlled by black plastic mulch, and suitable fumigants/herbicides must be applied if nutsedge is a potential problem. The cost of plastic removal is an additional expense. In most instances, plastic mulch culture has increased yields and returns sufficiently to offset these potential disadvantages.

Types of Plastic

One to 1¼ mil black plastic is the cheapest and has traditionally been most often used in spring pepper production. Embossed plastic has a reinforced woven component that minimizes the risk of tear elongation, which may occur with wind entry through a tear. This can be important, particularly in multiple cropping operations where, for example, spring peppers may be followed by fall cucumbers.

Summer planted pepper crops for fall production cannot tolerate excessively high soil temperatures. They should be planted on white plastic, which reflects some surface heat and does not heat the soil as much. For spring production however, white is not recommended since maximum soil warming is needed.

Recently, metalized mulches have become popular. These black plastic mulches have a thin film of metal that is applied with a vacuum. The metal produces a reflective effect. Research has shown that these mulches can help reduce the incidence of Tomato Spotted Wilt Virus infection on pepper by repelling thrips. Often, these plastics are produced with a black strip down the middle with the shoulders metalized. This allows for heat retention to get the earliness effect while producing the reflective effect needed to repel thrips and reduce TSWV.

Virtually Impermeable Films (VIF) are used in some parts of the world to reduce fumigant release into the atmosphere. These films are not yet routinely available in the United States, are more expensive and, depending on the fumigant, can increase the preplant interval.

Although biodegradable plastic mulches are presently available, they have not been proven to be beneficial. Since most growers want to grow two, three or four crops using the same plastic, biodegradable plastics break down too quickly to allow this. When perfected, these materials have the potential to greatly reduce the cost of plastic removal and disposal. Growers using a biodegradable plastic mulch for the first time should test it on a small area until its effectiveness under their conditions is proven.

Bed Preparation

Bed height and width depend on several factors including soil type, bedding equipment, available plastic, etc. Standard bed heights range from 4 to 8 inches. Bed width is also dictated by equipment and grower preference. Current top widths of beds range from 28 to 36 inches. Ordinarily plastic mulch must be 20 to 24 inches wider than the bed width pre-ferred so it will cover the sides of the bed and can be tucked under the soil to anchor the plastic. The plastic must fit firmly over the bed to minimize wind movement and facilitate planting. Cover mulch at the ends of each bed to prevent wind from getting under the plastic and fumigant from escaping. Any available opening, such as a tear or uncovered tuck, that allows wind entry will cause problems.

Use trickle or drip irrigation with plastic mulch for maximum efficiency. It is still important, however, to have optimum soil moisture during plastic application. The use of overhead irrigation requires punching additional holes in the plastic to facilitate water entry; this compromises the integrity of the plastic and reduces its effectiveness in controlling weeds and minimizing nutrient leaching.

Land preparation for laying plastic is similar to that described previously. The site should still be deep turned and rototilled. Usually a hipper is used to form a high ridge of soil down the middle of the bed to assure the bed pan is filled with soil. This creates a firm full bed. Generally, fumigant is applied as the bed pan passes and plastic is installed just behind the pan. Drip tape is installed at the same time just in front of the plastic and should be buried 1 inch below the surface to prevent "snaking" under the plastic and to reduce rodent damage. Soil moisture should be good at the time plastic is installed to ensure a good firm bed.

Fertilizer Management Under Plastic

Apply any needed lime 2 to 3 months ahead of plastic mulch installation. Preplant fertilizer application will vary with bed size and planting scheme. On larger beds (4 feet wide or greater) with double rows of peppers, it is advisable to incorporate all phosphorus and micronutrients into the bed before installation of plastic. If drip fertigation is not used, apply all the nitrogen and potassium preplant as well.

If smaller, single row beds are used, preplant application of all the needed fertilizer may cause fertilizer salt toxicity. Therefore, side-dressing is required by a liquid injection wheel, through drip irrigation, or a banded application outside the tucked portion of the bed.

Most pepper is planted where fertigation with drip irrigation is used. In these cases all the P and micronutrients and ⅓ to ½ of the N and K should be incorporated into the bed before the plastic is laid. Apply the remaining N and K through weekly fertigations beginning just after transplant establishment. The rate of application of these fertigations will change with the stage of the crop. See University of Georgia Cooperative Extension Bulletin No.

1108, *Plasticulture for Commercial Vegetable Production,* for a specific schedule of fertilizer injection recommendations.

Planting into Plastic Mulch

Peppers can be transplanted with a tractor mounted implement that uses a water wheel to punch holes in the plastic at the appropriate interval. A person (or persons) riding on seats mounted behind the water wheel(s) places a transplant into the newly formed hole and covers the rootball. This approach is rather slow, and a more common practice is to use a water wheel or similar device to punch holes with a crew of people walking the field and hand setting plants. Plants are then watered with a water wagon following the setting crews.

If a fumigant is used for soil sterilization, wait the prescribed time period before punching holes into the plastic. This will ensure good fumigant activity and avoid phytotoxicity. If an appropriate waiting period is not observed prior to planting, some soil fumigants can des-troy pepper transplant roots and cause stunting or plant death.

Irrigation

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Irrigation is essential to produce consistent yields of high quality peppers in Georgia. Rainfall amounts are often erratic during the pepper growing season, and peppers are often grown in sandy soils that have a low water holding capacity. This combination of factors makes supplemental irrigation necessary for commercial pepper production.

Irrigation studies in the Southeast show that irrigation increases annual pepper yields by an average of at least 60 percent over dryland production. Quality of irrigated peppers is also much better. Irrigation eliminates disastrous crop losses caused by severe drought.

Peppers are potentially deep rooted (up to 4 feet). In Georgia soils, however, the effective rooting depth is generally much less. Actual root depths will vary considerably, depending upon soil conditions and cultural practices. The effective rooting depth is usually 12 to 18 inches, and half of the roots will be in the top 6 inches. These roots should not dry out or root damage will occur.

Moisture stress in peppers causes shedding of flowers and young fruit, sunscalding and dry rot of fruit. The most critical stages for watering are at transplanting, flowering and fruit development.

Several types of irrigation may be used successfully on peppers in the Southeast; in Georgia, the majority of peppers are produced with drip irrigation. Ultimately, the type of irrigation chosen will depend on one or more of the following factors:

- Availability of existing equipment
- Field shape and size
- Amount and quality of water available
- Labor requirements
- Fuel requirements
- Cost

Sprinkler Irrigation

Sprinkler irrigation systems include center pivot, linear move, traveling gun, permanent set and portable aluminum pipe with sprinklers. Any of these systems are satisfactory if they are used correctly, but they are no longer commonly used in pepper production. There are, however, significant differences in initial cost, fuel cost and labor requirements among these systems.

Any sprinkler system used on peppers should be able to deliver at least an inch of water every 4 days. In addition, the system should apply the water slowly enough to prevent run-off. In sandy soils, the application rate should be less than 3 inches per hour. In loamy or clay soils, the rate should not exceed 1 inch per hour.

Sprinkler systems with a high application uniformity (center pivot, linear move and permanent set) can be used to apply fertilizer. This increases the efficiency of fertilizer use by making it readily available to the plant and reducing leaching.

Overhead irrigation also offers the most effective method of frost protection in pepper production; however, timely and complete coverage is required. The distance between sprinklers should be no more than 60 percent of the wetted diameter; place sprinklers no more than 50 percent of the sprinkler radius from the edge of the field. The nozzles should make at least one revolution per minute and should apply 0.12 to 0.15 inch of water per hour. Start sprinklers before the temperature drops to 32 degrees F (say 34 degrees F) and continue irrigating until the temperature rises and the ice begins to melt or until the wet-bulb temperature rises above 32 degrees F.

Drip Irrigation

Drip irrigation is the most popular method for pepper production in Georgia. Although it can be used with or without plastic mulch, its use is highly recommended with plastic mulch culture. A major advantage of drip irrigation is its water use efficiency. Studies in Florida indicate that drip irrigated vegetables require 40 percent less water than sprinkler irrigated vegetables. Weeds are less of a problem since only the rows are watered and the middles remain dry. Some studies have shown significant yield increases with drip irrigation and plastic mulch when compared with sprinkler irrigated peppers. The most dramatic yields have been attained by using drip irrigation, plastic mulch, and supplementing nutrients by injecting fertilizers into the drip system (fertigation).

Drip tubing may be installed on the soil surface or buried 2 to 3 inches deep. When used in conjunction with plastic mulch, the tubing can be installed at the same time the plastic mulch is laid. Usually one line of tubing is installed on each bed. If two rows of peppers are planted on a bed and they are not more than 12 inches apart, then both rows can be watered from the same drip line.

A field with beds spaced 5 feet center to center will require 8,712 feet of tubing per acre (one tube per bed). The output rate of the tube is specified by the user. For discussion purposes, you can determine the needed per-acre water capacity by multiplying the output rate of the tube (per 1,000') by 8.712 (ie., on a 5' bed spacing a 4.5 gpm/1,000' output rate tube will require 39.2 gpm per acre water capacity).

The tubing is available in various wall thicknesses ranging from 3 mils to 25 mils. Most growers use thin wall tubing (10 mils or less) and replace it every year. Heavier wall tubing can be rolled up at the end of the season and reused, but be careful removing it from the field and store in a shelter. Labor costs for removing, storing and reinstalling irrigation tubing are often prohibitive.

Excellent results have been achieved by injecting at least half of the fertilizer through the drip system. This allows plant nutrients to be supplied to the field as needed. This method also eliminates the need for heavy fertilizer applications early in the season, which tend to leach beyond the reach of root systems or cause salt toxicity problems.

Only water soluble formulations can be injected through the drip systems. Nitrogen and potassium formulations tend to be more water soluble than phosphorous and, consequently, are more easily injected. These nutrients also tend to leach quicker and need to be supplemented during the growing season. Drip systems should be thoroughly flushed following each fertilizer injection.

Water used in a drip irrigation system should be well filtered to remove any particulate matter that might plug the tubing. Test the water for minerals that could precipitate and cause plugging problems.

Scheduling Irrigation

The combined loss of water by evaporation from the soil and transpiration from plant surfaces is called *evapotranspiration* (ET). Peak ET rates for peppers are about 0.2 inch per day. Factors affecting ET are stage of crop growth, temperature, relative humidity, solar radiation, wind velocity and plant spacing.

Transplant peppers into moist soil and irrigate with 0.3 to 0.5 inch immediately after transplanting to settle the soil around the roots. Once a root system is established, maintain soil moisture to the 12-inch depth. The sandier soils in South Georgia have an available water holding capacity of about 1 inch per foot of soil depth. You should not deplete more than 50 percent of the available water before irrigating; therefore, when you use 0.5 inch, it should be replaced by irrigation. Soils having a higher clay content may have water holding capacities as high as 2 inches per foot. In these soils, you can deplete as much as 1 inch before irrigating. This means net application amounts should be between 0.5 and 1.0 inch per irrigation. The actual amount applied should be 10 to 20 percent higher to account for evaporation losses and wind drift.

The irrigation frequency will depend on daily evapotranspiration. In general, for sprinkler irrigated peppers during peak water use periods, sandy soils should receive 0.6 inch two or three times a week, and clay soils should receive 1.25 inches about every 5 days. Irrigation can best be managed by monitoring the amount of moisture in the soil. Soil moisture blocks can be used to measure soil moisture. For best results on peppers, maintain soil moisture below 30 centibars.

Drip irrigation systems need to be operated more frequently than sprinkler systems. Typically, they are operated every day or every other day. Do not saturate the soil with water, especially when using plastic mulch. Plastic mulch tends to keep the soil from drying out, and peppers grow poorly in waterlogged soil.

Physiological Problems

George Boyhan and W. Terry Kelley
Extension Horticulturists

Blossom Drop and Reduced Fruit Set

Blossom drop in pepper is primarily associated with high temperatures, particularly when night temperatures are above 70 degrees F. Such night temperatures can be common during mid-summer in Georgia. Spring production is best for peppers in reducing the incidence of blossom drop.

Other stress factors such as inadequate moisture can also contribute to blossom drop. Fruit load can also affect blossom retention. As fruit are set on a plant, additional flowers may drop or abort because the plant does not have sufficient resources to continue setting fruit.

Night temperature of 55 degrees F and below can also reduce fruit set by delaying flowering, affecting pollen viability, and affecting fruit morphology and size. Early plant growth is important in pepper production. Plants that have not reached sufficient size before flowering may produce fewer and smaller peppers. Maintaining optimum fertilization and water are important to ensure rapid early growth.

Use of floating row covers can help prevent cool temperature blossom drop during fall production, and black plastic mulch can help maintain warmer soils with greater moisture retention in the spring to ensure rapid growth.

Blossom-End Rot

Blossom-end rot is a physiological disorder of several vegetables including tomato, watermelon, squash and pepper. It is characterized as a dark brown to black necrotic region on the blossom end of developing fruit. This disorder is associated with calcium deficiency. Fruit losses can vary from negligible to economically devastating levels, depending on variety, weather, culture and soil type. Strong signs of calcium deficiency usually occur on fruit ⅓ to ⅔ mature.

The first external symptom to appear is a small water-soaked spot at or near the blossom end (opposite the stem) of the pepper. The water-soaked spot eventually enlarges with time and becomes dry, sunken, flattened, brown or black, and papery or leathery. Secondary attack by fungal or bacterial organisms may cause fruit rots, but these are not the primary causal factors.

Although the necrotic tissue associated with this disorder is calcium deficient, the development of the disorder has more to do with water relations. Calcium moves passively in plants, primarily in the xylem in the transpiration stream. Once incorporated into plant tissues, calcium is relatively immobile in the plant. Very little calcium moves downward in phloem tissue.

Several factors contribute to the development of this disorder. Since calcium moves into roots through the unsuberized tips of root hairs, any damage that occurs to these cells can interfere with calcium uptake. This can be particularly problematic during periods of fruit development. Damage to root hairs can occur from insects, diseases or nematodes. Cultivation that damages the roots or dry soil conditions can also damage these root hairs. Extremely wet soils can also be a factor in blossom-end rot, but whether this results from excess water or damage to root hairs is unclear.

During periods of rapid transpiration, as occurs during very hot weather, calcium may rapidly move to and accumulate in the growing tips but not move to developing fruit. This increases the likelihood of blossom-end rot.

Other nutrients may affect calcium uptake and thus the occurrence of blossom-end rot as well. Ammonium forms of nitrogen may inhibit calcium uptake while nitrate forms may increase its uptake. Calcium uptake may also be inhibited by excess magnesium or potassium. Under low pH conditions (<5.0) calcium uptake may be inhibited by aluminum, which competes for uptake sites. Finally, boron can have a synergistic effect on calcium uptake, increasing calcium uptake.

Preventing blossom-end rot usually involves ensuring adequate calcium is available to the plant, but, more importantly, maintaining a uniformly moist soil throughout the growing season. Excessive drying or water logging seems to increase the likelihood of this disorder as do swings from extremes of wet and dry soils.

Minimize damage to the roots by controlling soilborne insects and diseases (see the respective sections elsewhere in this guide). Crop rotation may help reduce the incidence of soilborne insect and disease problems. Cultivation should be shallow to prevent damage to the roots.

Fruits that begin to show symptoms of the disorder cannot be cured, but exogenous applications of calcium to the plant can help prevent the disorder. Most importantly, proper calcium levels in the soil coupled with the correct pH as well as maintaining evenly moist conditions are the best ways to prevent the problem.

Pepper Stippling

Pepper stippling is a physiological disorder that is also associated with calcium deficiency. Small (0.25 inch) spots occur inside the fruit wall as the pepper reaches maturity. These spots are brown or black and result in green or yellow spots occurring on the fruit surface. Potassium deficiency may also play a role in this disorder.

Newer varieties are available that are resistant to this stippling. This is probably the best method of control. Although seed companies are only claiming resistance to stippling, these resistant varieties may be helpful in controlling blossom-end rot.

Sunscald

Sunscald occurs when ripening fruit is not adequately shaded by leaf cover. Large sections of the exposed fruit can develop gray or brown paper-thin areas. These areas render the fruit unsalable. Selecting varieties that produce sufficient leaf canopy, preventing diseases and insects that defoliate the plant, and maintaining adequate fertility, particularly after fruit set, are important considerations in controlling this problem.

Poor Color Development

This occurs when peppers don't receive sufficient light into the canopy. This can be a particular problem when peppers are grown to full maturity and allowed to develop to colors beyond the initial green.

Nutrient and Other Disorders

Nutrient disorders beyond blossom-end rot can occur in peppers if fertilization is inadequate. Primary, secondary and micronutrient deficiencies and toxicities can occur but can be easily detected with soil testing, leaf tissue analysis or sap testing, and can be prevented or controlled with proper pH adjustment and proper fertilization (see section on fertilization).

Low soil pH can result in stunted plants that exhibit magnesium deficiency. Low pH can also contribute to toxicity from aluminum.

Toxicities can also occur due to applications of certain fungicides, particularly copper based materials, or due to non-target herbicide use that may be difficult to assess. Often this is due to material drift or improper waiting periods from applications to previous crops.

Lime and Fertilizer Management

W. Terry Kelley and George E. Boyhan, Extension Horticulturists and Darbie M. Granberry, Retired Extension Horticulturist

Lime and fertilizer management should be tailored to apply optimal amounts of lime and nutrients at the most appropriate time(s) and by the most effective application method(s). Fertilizer management is impacted by cultural methods, tillage practices, and cropping sequences. A proper nutrient management program takes into account native soil fertility and residual fertilizer. Therefore, the first step in an appropriate fertilizer management program is to properly take a soil test 3 to 5 months before the crop is to be planted.

Soil pH

Adjusting the soil to the appropriate pH range is the first consideration for any fertilizer management program. The soil pH strongly influences plant growth, the availability of nutrients, and the activities of microorganisms in the soil. It is important to keep soil pH in the proper range in order to produce the best yields of high quality peppers. Soil tests results indicate soil pH levels and also provide recommendations for any amounts of lime required to raise the pH to the desired range.

The optimum pH range for pepper production is 6.2 to 6.8. Most Georgia soils will become strongly acid (pH 5.0 or less) with time if lime is not applied. Continuous cropping and application of high rates of nitrogen reduce pH at an even faster rate. In addition to raising pH, lime also adds calcium and, with dolomitic lime, magnesium to the soil.

The two most common liming materials available in Georgia are calcitic and dolomitic limestone. Dolomitic limestone also contains 6 to 12 percent magnesium in addition to calcium. Since many soils, particularly lighter Coastal Plains soils, routinely become deficient in magnesium, dolomitic limestone is usually the preferred liming material.

Calcium has limited mobility in soil, therefore lime should be broadcast and thoroughly incorporated to a depth of 6 to 8 inches. This will also neutralize soil acidity in the root zone. To allow adequate time for neutralization of soil acidity (raising the pH), apply and thoroughly incorporate lime 2 to 3 months before seeding or transplanting. If application cannot be made this early, liming will still be very beneficial if applied and incorporated at least 1 month prior to seeding or transplanting.

Fertilizer Management And Application

Recommending a specific fertilizer management program universally for all pepper fields would result in applications that are inefficient and not cost effective. In addition to crop nutrient requirements and soil types, fertilizer recommendations should take into consideration soil pH, residual nutrients and inherent soil fertility. Therefore, fertilizer recommendations based on soil test analyses have the greatest potential for providing peppers with adequate but not excessive fertility. Applications limited to required amounts result in optimum growth and yield without wasting fertilizer, encouraging luxury consumption of nutrients, which can negatively impact quality, or causing fertilizer burn.

Recommendations based on soil tests and complimented with plant tissue analysis during the season should result in the most efficient lime and fertilizer management program possible. However, valid soil sampling procedures must be used to collect the samples submitted for analyses. To be beneficial, a soil sample must reliably represent the field or "management unit" from which it is taken. Soil samples that are improperly collected, compiled or labeled are of dubious benefit and may actually be detrimental. If there are questions about soil sampling, please contact your local county extension office for information.

In addition to lime application, preplant applications and in-season supplemental applications of fertilizer will be necessary for good crop growth and yield. In general, preplant applications are made prior to installation of plastic mulch. Research shows that broadcasting over the entire field is usually less effective than banding. An acceptable alternative to field broadcasting and one that is most often used with plastic mulch production, is the "modified broadcast" method, where the pre-plant fertilizer containing a portion of the nitrogen and potassium, and any recommended phosphorous and micronutrients, are broadcast in the bed area only. For example, on a 72-inch wide bed, a swath (24 inches to 48 inches wide) of fertilizer is uniformly applied centered over the bed and incorporated by rototilling. Additional applications are then made through the drip irrigation system. In bareground culture, preplant applications are followed by one to three sidedressed applications. The general crop requirements and application timings for the various nutrients are discussed below.

Starter Fertilizer Solution

Fertilizer materials that are dissolved in water and applied to the soil around plant roots at or just after transplanting are called *starter solutions.* When proper formulations and rates are applied, they can promote rapid root development and early plant growth. Starter solutions for pepper should contain a high rate of phosphorus (approximate ratio of 1 Nitrogen:3 Phosphorus:0 Potassium is common) and should be mixed and applied according to the manufacturer's directions. Common starter solutions consist of 3 pounds of a formulated material (such as 10-34-0, which weighs approximately 11 lbs./gallon) mixed in 50 gallons of water. Approximately ½ pint of the starter solution is normally applied per plant. In addition to supplying phosphorus, which may be inadequately available (especially in cold soils in the early spring), the starter solution supplies water and firms the soil around roots. This helps eliminate air pockets that can cause root drying and subsequent plant or root damage. A starter solution is no substitute for adequate rainfall or irrigation after transplanting, however.

Be careful to mix and apply starter fertilizer according to the manufacturer's recommendations. If the starter solution is too highly concentrated (mixed too strong), it can kill plant roots and result in dead or stunted plants. When mixing and applying from a large tank, mix a fresh solution only after the tank becomes empty. This helps prevent the gradual increase in concentration that will occur if a portion of the previous mix is used for a portion of the water component in subsequent batches. If a dry or crystalline formulation is used, be sure it is thoroughly mixed and agitated in the tank, since settling can result in streaks of highly concentrated application that can stunt or kill plants as well.

Phosphorus and Potassium Recommendations

The following chart indicates the pounds of fertilizer nutrients recommended for various soil P and K levels according to University of Georgia soil test ratings of residual phosphorus (P_2O_5) and potassium (K_2O).

All the recommended phosphorus should be incorporated into the bed prior to plastic mulch installation or, for bare ground production, applied during or near transplanting. Approximately ½ pint of a starter solution, as described above, should be applied to each transplant. For bare ground production, around 100 to 150 pounds per acre of a pop-up fertilizer promotes earlier growth, particularly in cool/

cold soils. A good pop-up fertilizer is similar to or equal to 10-34-0. It should be relatively high in phosphorus and low in potassium. For early growth stimulation, pop-up fertilizer should be banded 2 to 3 inches to the side of the plants and 2 to 3 inches below the roots.

Phosphorus and Potassium Recommendations

Phosphorus Ratings	Low	Medium	High	Very High
Recommended P	120	80	40	0
Potassium Ratings	Low	Medium	High	Very High
Recommended K	120	90	60	30

P - Represents pounds of P2O5 recommended per acre;
K - Represents pounds of K2O recommended per acre.

Note: If soil testing is done by a lab other than the University of Georgia Soils Testing Laboratory, the levels recommended above may not apply.

One-third to one-half of the potassium should either (1) be incorporated into the bed prior to installing plastic mulch, or (2) be applied in two bands, each located 2 to 3 inches to the side and 2 to 3 inches below the level of plant roots for bare ground production. The remainder of the recommended potassium should be applied through the drip system according to the schedule in Table 2 or, for bare ground culture, in one to three applications as needed. It can be banded in an area on both sides of the row just ahead of the developing root tips. The maximum number of applications is usually more effective on sandy soils.

Nitrogen Recommendations

Typical Coastal Plains soils require a total of 150 to 200 pounds of nitrogen (N) per acre. Extremely sandy soils may need additional N or an increased number of applications. Piedmont, Mountain and Limestone Valley soils usually require only 100 to 150 pounds of N per acre for pepper production.

N rates actually needed will vary depending on rainfall, soil type, soil temperature, irrigation, plant population, duration of the harvest season, and method and timing of applications.

For typical Coastal Plains soils, one-fourth to one-third of the recommended nitrogen should either (1) be incorporated into the bed prior to plastic installation or (2) with bare ground culture, applied in two bands, each located 2 to 3 inches to the side and 2 to 3 inches below the level of plant roots. Apply the remaining recommended N through drip irrigation according to the schedule in Table 2. On bare ground, one to three side-dressed applications (possibly four to five applications with extended harvest period on very sandy soil) are needed. It can be banded in an area on both sides of the row just ahead of the developing root tips. For heavier Piedmont, Mountain and Limestone Valley soils, one to two applications are usually sufficient.

Approximately 50 percent of the total applied N should be in the nitrate form. High rates of ammoniacal nitrogen may interfere with calcium nutrition and result in an increased incidence of blossom-end rot (BER).

Table 2. An example fertilizer injection schedule for a Coastal Plains soil that is very low in potassium. The schedule is for a typical 14-week crop. Extended harvests will require additional injection applications.

Nutrient	Total	Preplant	Crop State in Weeks (lbs/A/day)					
	(lbs/A)	(lbs/A)	1-2	3-4	5-6	7-10	11-12	13-14
Nitrogen	225	50	1.0	1.5	2.0	2.5	2.0	1.5
Potassium	175	0	1.0	1.5	2.0	2.5	2.0	1.5

Side dressing or fertigating with calcium nitrate as the nitrogen source often significantly reduces the severity of BER.

Magnesium, Sulfur, Zinc And Boron Recommendations

If the soil test indicates magnesium is low and if lime is recommended, apply dolomitic limestone. If magnesium is low and lime is not recommended, apply 25 pounds of elemental magnesium per acre. Apply a minimum of 10 pounds of sulfur per acre, 1 pound of actual boron per acre and, if soil test indicates zinc is low, apply 5 pounds of actual zinc per acre. These nutrients should be supplied in the preplant fertilizer application.

Foliar Application of Fertilizer

The fact that plants can absorb some fertilizer elements through their leaves has been known for some time. However, leaves of many vegetable plants are not especially well adapted for absorbing nutrients because of a waxy cuticle. In some instances, plants that seem to benefit from foliar uptake are actually benefitting from nutrient spray that reaches the soil and is taken up by roots.

The effectiveness of applying macronutrients such as nitrogen, phosphorus and potassium to plant leaves is questionable. It is virtually impossible for pepper plants to absorb enough N, P or K through the leaves to fulfill their nutritional requirements; furthermore, it is unlikely that they could absorb sufficient amounts of macronutrients to correct major deficiencies. Although nitrogen may be absorbed within 24 hours after application, up to 4 days are required for potassium uptake and 7 to 15 days are required for phosphorus to be absorbed from foliar application.

The crucial question is whether or not foliar N, P or K actually increases yield or enhances quality. Although some growers feel that foliar fertilizer should be used to supplement a soil applied fertilizer program, research findings do not support this practice. If a proper soil applied fertilizer program is used, additional foliar fertilization is not usually required.

Foliar nutrients are often expected to cure a variety of plant problems, many of which may be unrelated to nutrition. They include reducing stress-induced blossom drop, aiding in healing frost or hail damaged plants, increasing plant resistance to various stresses and pests, etc. Nutrients are only effective as long as they are supplying a nutritional need; however, neither soil-applied nor foliar-applied nutrients are panaceas.

Quite often after frost or hail occurs, pepper growers apply foliar nutrients to give the plants a boost to promote rapid recovery. However, if a proper fertilizer program is being used before foliage damage, pepper plants don’t need additional fertilizer. What they do need is time and the proper environment for the normal recovery processes to occur. In addition, the likelihood of significant nutritional benefits from a foliar application of fertilizer to plants that have lost most of their leaves (or have a large proportion of their leaves severely damaged) is questionable.

Foliar application of sulfur, magnesium, calcium and micronutrients may help alleviate deficiencies. They should be applied, however, only if there is a real need for them and only in quantities recommended for foliar application. Application of excessive amounts can cause fertilizer burn and/or toxicity problems.

Foliar applications of calcium nitrate or calcium chloride (one to three weekly applications beginning at first bloom or at first sign of BER) may reduce the incidence of blossom-end rot (BER), but results are highly variable. The recommended rate is 3 to 4 pounds in 100 gallons of water per acre.

Two to three foliar applications of water soluble boron (approximately 1 to 2 ounces by weight of actual boron per application) at weekly intervals coinciding with flowering has, in some instances, enhanced fruit set. A commercial formulation that contains both boron and calcium (2 to 3 ounces by weight of calcium per application) may be applied. Follow manufacturer's directions when applying any commercial calcium/boron formulations.

Plant Tissue Analysis and Petiole Sap Analysis

Plant tissue analysis or petiole sap analysis is an excellent tool for measuring the nutrient status of the crop during the season. Particularly with fertigation, it is simple to adjust fertilizer injection rates according to the analysis results. Sufficiency ranges for tissue analysis are given in Table 3 and are for early bloom stage with the sample taken from the most recently mature leaf.

Fresh sap can be pressed from the petioles of pepper plants and used to determine nitrogen and potassium nutritional status. Sufficiency ranges for these are listed in Table 4.

Table 3. Plant tissue analysis ranges for various elements for pepper sampled at the early bloom stage with most recently mature leaves.

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
Status	Percent						Parts per Million					
Deficient	<3	0.3	2.5	0.6	0.3	0.3	30	30	25	20	5	0.2
Adequate	3-5	0.3-0.5	2.5-5	0.6-1.5	0.3-0.5	0.3-0.6	30-150	30-100	25-80	20-50	5-10	0.2-0.8
High	>5	0.5	5	1.5	0.5	0.6	150	100	80	50	10	0.8

Table 4. Sufficiency ranges for petiole sap tests for pepper at various stages of crop development.

Crop Development Stage	Fresh Petiole Sap Concentration	
	NO_3-N	K
First Flower Buds	1400-1600	3200-3500
First Open Flowers	1400-1600	3000-3200
Fruits Half Grown	1200-1400	3000-3200
First Harvest	800-1000	2400-3000
Second Harvest	500-800	2000-2400

Sprayers

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Extension Engineer

The equipment used for applying liquid insecticides, fungicides, herbicides and foliar fertilizers are classified as sprayers. Basically, there are two types of sprayers recommended for spraying peppers — hydraulic and air-curtain boom. The key to maximum coverage with insecticide and fungicides is the ability of the air within the plant canopy to be replaced with pesticides.

The **air-curtain booms**, or "air-blast sprayers" (Figure 1) are designed with an external blower fan system. The blower creates a high velocity of air that will "entrain" or direct the spray solution toward the target. Some sprayers provide a shield in front of or behind the conventional spray pattern, protecting the spray from being blown off-target.

The concept of this approach is to increase the effectiveness of pest-control substances, provide better coverage to the undersides of leaves, promote deeper penetration into the crop canopy, make it easier for small droplets to deposit on the target, cover more acres per load, and reduce drift.

Studies conducted by the U.S. Department of Agriculture Agricultural Research Service in Stoneville, Mississippi, have shown that the air-assisted sprayers tended to show improved insect control in the mid- to lower canopies. The air stream tended to open the canopy and help spray particles penetrate to a deeper level. Mid- to lower-canopy penetration and coverage is important when working with insecticides and fungicides but may not be as critical when applying herbicides.

Figure 1. Air-assisted boom sprayer.

Figure 2. Hydraulic boom sprayer.

The **hydraulic boom** sprayers (Figure 2) get their name from the arrangement of the conduit that carries the spray liquid to the nozzles. Booms or long arms on the sprayer extend across a given width to cover a particular swath as the sprayer passes over the field. Each component is important for efficient and effective application.

Most materials applied by a sprayer are a mixture or suspension. Uniform application demands a uniform tank mix. Most boom sprayers have a tank agitator to maintain uniform mixture. The agitation (mixing) may be produced by jet agitators, volume boosters (sometimes referred to as hydraulic agitators) or mechanical agitators. These can be purchased separately and put on sprayers. Make sure an agitator is on every sprayer. Some growers make the mistake of not operating the agitator when moving from field to field or when stopping for a few minutes. Agitate continuously when using pesticides that tend to settle out.

Nozzles

Nozzle tips are the most neglected and abused part of the sprayer. Since clogging can occur when spraying, clean and test nozzle tips and strainers before each application. When applying chemicals, maintain proper ground speed, boom height and operating pressure. This will ensure proper delivery of the recommended amount of pesticide to the plant canopy.

Herbicides

The type of nozzle used for applying herbicides is one that develops a large droplet and has no drift. The nozzles used for broadcast applications include the extended range flat fan, drift reduction flat fan, turbo flat fan, flooding fan, turbo flooding fan, turbo drop flat fan and wide angle cone nozzles. Operating pressures should be 20 to 30 psi for all except drift reduction and turbo drop flat fans, flooding and wide angle cones. Spray pressure more than 40 psi will create significant spray drift with flat fans nozzles. Drift reduction and turbo drop nozzles should be operated at 40 psi. Flooding fan and wide angle cone nozzles should be operated at 15 to 18 psi. These nozzles will achieve uniform application of the chemical if they are uniformly spaced along the boom. Flat fan nozzles should be overlapped 50 to 60 percent.

Insecticides and Fungicides

When applying insecticides and fungicides, use solid or hollow cone type nozzles. The two patterns that are developed by solid or hollow cone nozzles can be produced by different tip configurations. One type tip, disc-n-core, consists of two parts. One part is a core (swirl plate) where the fluid enters and is forced through tangential openings. Then a disc-type hardened stainless steel orifice (opening) is added. Another type of tip that produces the same patterns is of one-piece construction (nozzle body). In this type of tip, liquid is passed through a precision distributor with diagonal slots, which produce swirls in a converging chamber. The resulting pattern of both tip configurations is either solid or hollow cone. Even fan and hollow cone nozzles can be used for banding insecticide or fungicides over the row.

Nozzle Arrangement

When applying insecticides and fungicides, it is advantageous to completely cover both sides of all leaves with spray. When spraying peppers, use one or two nozzles over the top of the row (up to 8 inches wide). Then, as the plants start to grow and bush, adapt the nozzle

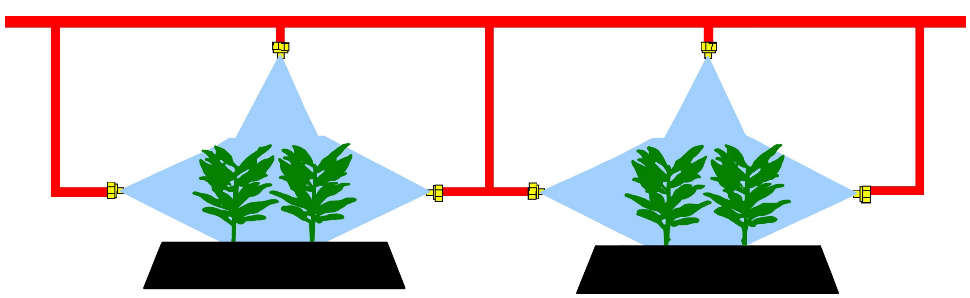

Figure 3. Use one nozzle over the row up to 8 inches, then change to three nozzles for optimum coverage of the pepper plant.

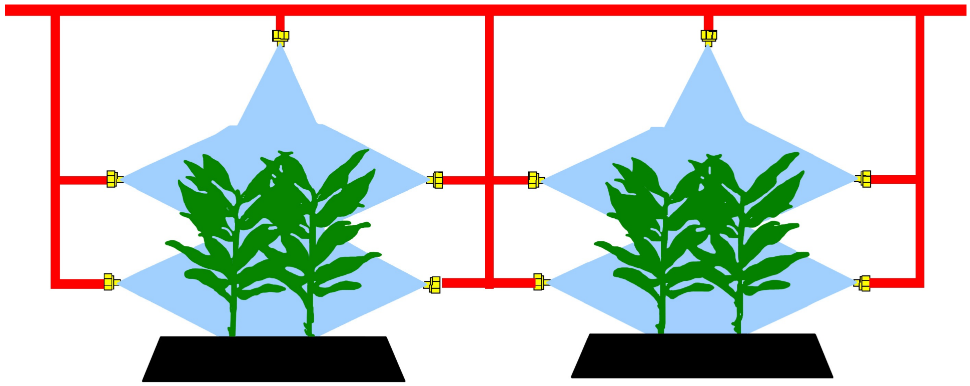

Figure 4. Add more pairs of nozzles as the plants grow taller and thicker.

arrangement for the various growth stages of plants (Figures 3 and 4).

Opposing nozzles should be rotated clockwise slightly so that spray cones do not collide. This will guarantee that the spray is applied from all directions into the canopy. As the plant increases in height, add additional nozzles for every 8 to 10 inches of growth. In all spray configurations, the nozzle tips should be 6 to 10 inches from the foliage. Properly selected nozzles should be able to apply 25 to 125 gallons per acre when operating at a pressure of 60 to 200 or higher psi. Usually, more than one size of nozzle will be needed to carry out a season-long spray program.

Calibration

Calibrate sprayers often. Calibration should be conducted every 8 to 10 hours of operation to ensure proper pesticide application. A good calibration procedure to follow is *Calibration Method for Hydraulic Boom and Band Sprayers and Other Liquid Applicators,* University of Georgia Extension Circular 683. This circular is available through local county extension offices and on the web at:

http://pubs.caes.uga.edu/caespubs/pubcd/C683.htm

Diseases

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Plant diseases are one of the most significant limiting factors to pepper production in Georgia. The hot, humid climate coupled with frequent rainfall and mild winters favor the development of many pathogens and the diseases they cause.

Bacterial Diseases

Bacterial spot is the most common and often the most serious disease affecting peppers in Georgia. This disease is caused by the bacterium *Xanthomonas campestris pv. vesicatoria*. Bacterial spot lesions can be observed on leaves stems and fruit, and occurs on all stages of plant growth. Leaf lesions usually begin as small, water-soaked lesions that gradually become necrotic and brown in the center (Figure 5). During wet periods the lesions appear more water-soaked. Lesions generally appear sunken on the upper surface and raised on the lower surface of infected leaves. During periods of favorable weather, spots can coalesce and cause large areas of chlorosis (Figure 6). Premature leaf drop is the ultimate result of leaf infection. Fruit lesions appear as small, round, dark brown to black spots.

The bacterium is primarily seed-borne, and most epidemics can be traced back, directly or indirectly, to an infected seed source. Infected seedlings carry the disease to the field where it spreads rapidly during warm, wet weather. Workers working in wet fields can also be a major source of disease spread.

All pepper seed planted for transplants or direct seeded field grown peppers should be tested by a reputable seed testing company. Transplants should be inspected for bacterial spot lesions before being sold or planted in the field.

Prevention is the best method for suppressing losses to bacterial spot. Purchase seed from companies that produce the seed in areas where the disease is not known to occur. Hot water seed treatment can also be used and pepper seed can be soaked in water that is 125 degrees F for 30 minutes to kill the bacterium.

Transplant production should take place in areas away from commercial production so as to avoid contamination from production fields or vice versa. Use of resistant varieties is the next line of defense and most commercial varieties have resistance to some of the known races of bacterial spot. Rotate away from fields where pepper has been grown within the past

Figure 5. Bacterial spot lesions on a pepper leaf.

Figure 6. Leaf chlorosis caused by bacterial spot.

Figure 7. TSWV ringspots on pepper foliage.

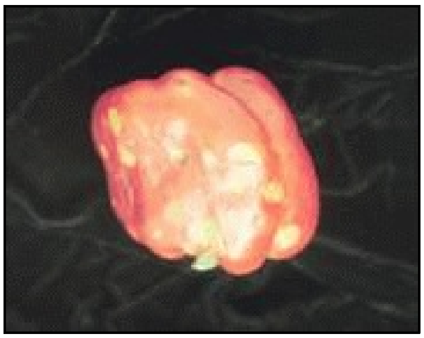

Figure 8. TSWV raised ringspots on pepper fruit.

Figure 9. TSWV black specks on pepper fruit.

Figure 10. CMV effects on pepper fruit.

year and use practices that destroy volunteers that could allow the disease to be carried over to a subsequent crop.

Cull piles should be away from production fields or transplant houses. Copper fungicides used in conjunction with maneb will suppress disease losses if applied on a preventive schedule with a sprayer that gives adequate coverage.

Virus Diseases

Virus diseases have been a severe limiting factor in pepper production in Georgia for several years. Most virus diseases cause stunting, leaf distortion, mosaic leaf discoloration, and spots or discoloration on fruit. The dissemination of virus-infected plants is usually random with symptomatic plants often bordered on either side by healthy, non-symptomatic plants. Virus diseases are almost always transmitted by insect vectors, and the severity of a virus disease is usually tied to the rise and fall in the populations of these vectors from season to season and within a given season. However, some virus diseases are seed and mechanically transmitted. Only the viruses that have been the most problematic on pepper in Georgia will be covered in this section.

Tomato spotted wilt virus (TSWV) is one of the most common viruses affecting pepper in the southeastern United States. This virus is transmitted by thrips and can affect pepper at any stage of development. The extensive host range of TSWV in weeds allows for a continual source of inoculum for infection. However, as with any virus disease, early infections tend to cause more yield losses than those occurring later in plant development. TSWV causes plant stunting, rosetted leaves, ringspots (Figure 7), mottling, mosaic, bronzing and terminal necrosis on infected plants.

Pepper fruit produced on infected plants may be misshapen, have raised ringspots (Figure 8), or have small black specks (Figure 9). TSWV in Georgia pepper has been suppressed through the use of black plastic and other colored mulches, particularly reflective mulches, as well as with resistant varieties.

Cucumber mosaic virus (CMV) is a very common disease of pepper and can be very devastating where it occurs. This virus is transmitted by aphids and can be maintained in several weed species that surround production fields. Symptoms of CMV are very variable and range from almost no symptoms to severe stunting and mottling, and necrosis of foliage. In some instances, fruit produced on infected plants will be distorted and begin to break down on the distal end (blossom end) of the fruit, particularly in the seams that separate the capsules (Figure 10, page 26). However, some fruit have only mild discoloration and distortion.

Pepper varieties that are resistant to CMV have been described and would be very useful, however commercially acceptable varieties for Georgia growers have not been made available. Use of reflective mulches may help reduce aphid transmission as will reduction of the weed reservoir surrounding fields.

Pepper mild mottle virus (PMMV) is a virus that has only recently caused losses in several pepper types in Georgia. This virus is primarily seedborne and spreads through the field mechanically by workers. Symptoms on foliage have been rather mild but a chlorotic mosaic pattern has been observed in some instances. Symptoms on fruit have been more predominant in Georgia and appear as irregular, sunken, discolored areas (Figure11). Control of PMMV is best achieved through the use of non-infected seed.

Figure 11. PMMV sumptoms on pepper fruit.

Fungal Diseases

Cercospora leaf spot caused by *Cercospora capsici*. This disease is somewhat rare in Georgia but has been reported throughout the southeast. Symptoms appear as small, round to oblong lesions with light gray centers on the leaves, stalks and leaf stems (Figure12). A dark border on the inside margin of the lesion is often observed. Infected leaves generally shed prematurely. The disease may be seed-borne, and infection may be traced to infected seedlings grown from contaminated seed. The disease can also be carried over on crop debris. Wet, humid weather favors disease development. In the field the fungus spores are spread mainly by wind. Unless controlled, it causes severe defoliation. The disease is easily controlled with chemical sprays. Spray programs used for bacterial leafspot and anthracnose will suppress *Cercospora* leaf spot.

Figure 12. Cercospora leaf spot lesions on a leaf.

Anthracnose caused by *Colletotrichum acutaum* and *gloeosporioides*. Both of these fungi cause diseases primarily on fruit with *C. gloeosporioides* causing disease on ripe fruit and *C. acutatum* causing disease on both immature and ripe fruit. Lesions are usually round and sunken and can be over an inch in diameter depending on the size of the fruit. Initially, lesions will contain a small area of tan to pink sporulation near the center (Figure 13). Older lesions contain concentric rings of pink or salmon colored conidial sporulation. In Georgia, *C. acutatum* has recently been shown associated with the more serious outbreaks. Anthracnose can be introduced to a field through contaminated seed or be sustained in infested plant debris. This disease is favored by warm, wet, humid weather. This disease is best controlled by using disease-free seed and rotating away from fields with a known history of losses to anthracnose. Preventive fungicide applications are also recommended.

Figure 13. Anthracnose lesions on pepper fruit.

Phytophthora fruit and crown rot caused by *Phytopthora capsici*. Phytopthora is a fungal-like organism that is in a separate kingdom than the fungi. It is a water-mold, oomycete organism that has a mobile swimming-spore stage as part of its life cycle. This particular disease is one of the most common and arguably the most destructive disease of pepper in Georgia, rivaled only by bacterial spot and TSWV in order of importance and yearly yield losses. Symptoms of Phytophthora fruit and crown rot are usually dead or wilted plants that begin dying in the section of the field that is most poorly drained. The crown region of the plant near the base is usually darkened, sunken and necrotic (Figure 14). Vascular discoloration can be observed in tissues above the ground. The disease generally spreads to other areas of the field through moving water (either irrigation or rain), equipment or workers. The foliar and fruit phase of the disease is rarely observed in Georgia. Control of Phytophthora fruit and crown rot is achieved by avoiding fields with a history of the disease, both in pepper and other crops.

Figure 14. Pepper plant with Phytophthora crown rot.

If ponds are used for irrigation, they may be contaminated with the disease and should be identified and avoided. Resistant varieties have recently been made available that show good to fair resistance to this disease. Fungicide applications have been recommended and do show some benefits but fungicide resistance problems coupled with the subterranean nature of the organism hinder consistent performance of preventive or remedial fungicide treatments.

Southern stem rot caused by *Sclerotium rolfsii*. This is a common destructive disease of peppers in Georgia. Since many peppers are rotated with peanuts, soybeans and other susceptible crops, the disease has become a major problem. The fungus attacks the stem of the plants near or at the soil line and forms a white mold on the stem base. Later in the season, small, round brown bodies appear in the mold (Figure 15). Infected plants wilt and slowly die.

Figure 15. Base of plant infected with southern stem rot.

Vascular discoloration can be observed in stem tissues above the lesion. The severity of this disease can be lessened by following good cultural practices: rotation, litter destruction and deep turning with a moldboard plow are the best cultural defenses against this disease. Fumigation as well as at-plant and drip-applied fungicides are also effective in reducing losses to southern stem rot.

Nematodes

Root-knot nematodes (*Meloidogyne* spp.) can cause serious economic damage to peppers. These tiny worms live in the soil and feed on the roots of peppers. Not only do they cause physical damage that interferes with the uptake of water and nutrients, but they allow the establishment of other diseases. Nematode infected plants are generally stunted with pale green to light yellow foliage. Symptoms may be temporarily masked by supplying additional fertilizer and water. Soils infested with root-knot nematodes should be avoided or treated with fumigant or chemical nematicides before peppers are planted.

Insect Management

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Extension Entomologist

While many insects that feed on pepper are only occasional pests in Georgia, a few species are common pests and occur annually. Insect pests can damage pepper throughout the growing season, but severity varies with location and time of year. The severity of damage to pepper by insect pests is largely due to abundance of the pests, which is related to environmental conditions. While we may be able to predict the potential for pest outbreaks, it is difficult to predict whether control measures will be required for most pest. For example, we know that caterpillar pests, whiteflies and broad mites have a much greater potential to damage the crop in the fall, but we cannot predict if control measures will be needed.

Knowledge of pests' habits, careful pest monitoring, and timely use of effective control measures does enable growers to avoid or at least reduce the damage they suffer. Pepper is well suited for insect pest management.

Because a variety of insects may attack pepper, scheduled sprays are frequently considered for insect management. Scouting two to three times per week, however, which allows for early detection of infestations and timely application of pest specific control measures, is the most cost-effective management strategy for most pests. Possible exceptions to this are the management of thrips that vector TSWV or fields with a history of specific pest problems that require preventive control or are difficult to manage with curative treatments.

When insecticidal control is determined to be necessary, use the *Georgia Pest Management Handbook* help you select the correct insecticide for control of specific insect pests.

Seedling Pests

Cutworms. Young pepper transplants may be cut down just above the soil surface by cutworms. While the damage is readily apparent, the insects are difficult to detect during the day, as the larvae typically hide in the ground. Detecting the insects and verifying the pest problem is most easily accomplished when larvae feed at night.

The majority of cutworms pass the winter in the soil as full-grown larvae and cutworm damage can be particularly abundant in fields where grass sod was the previous crop or in previously fallowed fields with heavy weeds. Greatest damage is often found in wet areas of the fields but can also be concentrated on field margins where cutworms are moving in from adjacent areas.

Cutworms are generally considered a seedling pest, but they may also feed on foliage and pods of mature plants. Use preventive insecticide treatments on fields with a history of cutworms or on pepper fields following grass sod. Where preventive treatments are not used, use directed sprays for cutworm control when 5 percent of the seedlings have been damaged or destroyed and cutworms are still present. All directed or foliar sprays used for cutworm control should be applied late in the day when cutworms are active.

Other insects attacking the main stem of seedlings. Several occasional pests may cause damage similar to cutworms. White grubs (immature stage of May beetles and June beetles) may cut off plants, but they will typically cut plants slightly below the soil line as compared to cutworms, which will usually cut at or slightly above the soil line. Vegetable weevils, crickets and grasshoppers may also attack the main stem of seedlings. Generally these pests do not cut off plants except for the smallest transplants. They tend to feed up and down the main stem, removing the softer outer tissue and can completely girdle the plant. This damage generally results in plant death and, at the least, makes the plant susceptible to lodging and seedling diseases.

Thrips. Thrips may be present in pepper fields throughout the growing season but are generally more prevalent in the spring. Prior to plants blooming, tobacco thrips generally dominate the population, as this species readily feeds and reproduces on foliage. Flower thrips species populations can increase dramatically once blooming and pollen availability increases. Flower thrips populations may increase prior to the crop blooming if outside sources of pollen are plentiful. Knowledge of which species is present in a field can impact control decisions, because insecticides can provide very different levels of control for different species.

Plant injury is caused by both adult and immature thrips puncturing leaf and floral tissues and then sucking the exuding sap. This causes reddish, gray or silvery speckled areas on the leaves. With severe infestations these areas can interfere with photosynthesis and result in retarded growth. Heavy infestations during the bloom stage may cause damage to developing pods. This damage appears on pods as dimples with necrotic spots in the centers. Occasionally thrips aggregate on pods well hidden from sprays. This may result in russeting damage from continual feeding during pod development.

For prevention of direct damage, apply insecticides when 20 percent of plants show signs of thrips damage, or when 10 or more thrips per bloom are found. Thrips are very small, so close observation is necessary. Thrips may be monitored in a variety of ways including various methods of beating plants to dislodge thrips from foliage into a collection device (Styrofoam cup, white tray, sticky trap). An effective in-field survey method for thrips in blooms is to place several blooms in a vial of alcohol and count the thrips as they die and settle to the bottom.

Figure 16. Adult thrips under high magnification.

While thrips can cause direct damage to foliage and fruit, their role as vectors of tomato spotted wilt is of primary concern in Georgia.

Where TSWV is of concern, virus resistant varieties are frequently grown. For prevention of TSWV in susceptible varieties, UV-reflective plastic mulch has proven useful in suppression of thrips populations and virus incidence, although this benefit has been better documented in tomatoes than peppers. Insecticides also are frequently used in a preventive manner where TSWV is of concern.

Foliage Feeders

Aphids. Aphids or plant lice are small, soft-bodied insects that may feed on pepper plants from time of planting until last harvest. Aphids cluster in shaded places on leaves, stems and blossoms. While winged migrants move from field to field spreading virus diseases, host plant resistance in peppers has helped minimize this problem.

Feeding by aphids causes newly formed leaves to be crinkled and malformed. Large populations of aphids on young plants can cause wilting and stunting. At harvest, infestations can represent a contamination both through their presence and through production of honeydew, which gives rise to sooty mold.

Figure 17. Honeydew and sooty mold caused from aphid infestation.

Establishment of aphid colonies on pepper is often reduced by wet weather, but during cool, dry weather, large numbers of aphids may develop quickly. Aphid populations can be assessed by examining terminals and the undersides of leaves. Treatments for aphids in early spring plantings may be postponed until distinct colonies of immature aphids are found. If aphid-transmitted viruses are of concern, initiate treatments for aphids in late summer plantings when winged adults are found on young plants. Prior to harvest, control aphids if honeydew or sooty mold is found on developing pods.

Colorado Potato Beetle. Colorado potato beetles rarely occur in damaging numbers in pepper fields. They lay orange-yellow eggs in groups of a dozen or more on the undersides of leaves; these eggs are often mistaken for lady beetle eggs. Injury to peppers is due to actual consumption of foliage and stems by the chewing adults and larvae. Young plants may be completely defoliated.

In pepper-growing areas where spraying for insect control is a regular practice, insecticides have so reduced the population that it is no longer a serious problem. In some areas, however, control of this insect still demands attention. Colorado potato beetles occur in large numbers and are generally uniformly distributed over an area. Because of their short life cycle and high reproductive capacity, treatments are needed as soon as beetle eggs or larvae are found.

Flea Beetles. The name *flea beetle* applies to a variety of small beetles, with enlarged hind legs, which jump vigorously when disturbed. Their injury consists of small, rounded or irregular holes eaten through or into the leaf. The most common flea beetles on pepper are about 1/16 inch long and nearly a uniform black in color.

Flea beetles may attack peppers at any time during the growing season but are often most numerous and of greatest concern early in the season. Apply insecticides for control of flea

Figure 18. Flea beetle adult.

Figure 19. Hornworm caterpillar.

Figure 20. Cabbage looper larva.

Figure 21. Leafminer mines in a leaf.

beetles when flea beetles become numerous and defoliation is greater than 10 percent. Flea beetles generally do not require control once plants are beyond the 5-leaf stage.

Hornworms. Hornworms are large, green, caterpillars with white diagonal markings. They reach a length of 3 inches. The most distinguishing characteristic of hornworms is the slender horn projecting backward from the rear of the body. The predominant species in Georgia is the tobacco hornworm.

Hornworms do not attack fruit, eating only the foliage of pepper plants, but they may cause enough defoliation to allow sunscald of pods. The adult moths deposit spherical translucent eggs, singly on the undersides of leaves. Treatments for hornworm control should be applied when larvae are found on 4 percent of the plants examined.

Cabbage Looper. The cabbage looper is the most common looper in peppers in Georgia. They are foliage feeders; damage to fruit is rare. Larvae chew irregular holes in leaves. Leaf damage is of concern only when large numbers of larvae attack small plants or if feeding is extensive enough to open the canopy, exposing fruit to sunburn. Mature plants can tolerate multiple larvae per plant without significant loss.

Looper eggs are laid singly on plants and can be confused with tomato fruitworm eggs; however, looper eggs are flatter than fruitworm eggs and have finer ridges radiating from the top of the egg. Looper larvae are easily identified by their habit of arching their backs into a loop as they crawl. Loopers are frequently controlled by insecticide applications applied for other caterpillar pests and are usually not a significant problem in peppers in Georgia.

Leafminers. Adult leafminers are tiny, shiny, black flies with yellow markings. Adult female flies lay eggs within the leaves and white to pale yellow larvae with black mouthparts mine between the upper and lower leaf surface for about five to seven days before dropping to the ground to pupate. As the larvae grows and consumes more leaf tissue, the winding mine increases in diameter. Leafminer infestations usually are first detected as these slender, white, winding trails caused by the larvae. (See Figure 21 on page 32.) The leaves are greatly weakened and the mines may serve as points where decay and disease may begin. With severe infestations, heavy leaf loss may lead to sun scald of fruit.

Several parasites attack this pest and can keep leafminer populations under control. Leafminers rarely pose a serious threat to pepper production in Georgia except in fields where their natural enemies are reduced by early, repeated insecticide applications. Begin treatments for leafminer control when populations reach an average of five mines/trifoliate (a trifoliate is the three leaflets at the terminal end of the leaf) with at least 25 percent of mines containing live larvae.

Spider Mites. Spider mites appear to be developing into a more consistent pest in south Georgia. They generally feed on the underside of leaves, but they can cover the entire leaf surface when populations are high. The minute, eight-legged mites appear as tiny, reddish, greenish or yellow moving dots on the undersides of leaves. Because of their size, the first detection of spider mite infestations is usually damage to the leaves. Leaves of pepper plants infested with spider mites are initially lightly stippled with pale blotches. In heavy infestations, the entire leaf appears light in color, dries up, often turning reddish-brown in blotches or around the edge and may be covered with webbing.

The greatest damage to peppers occurs during dry, hot weather, which is favorable for development of extremely large mite populations. Spider mites are also generally considered a secondary pest, with damaging populations frequently occurring after application of broad spectrum insecticides.

To check for spider mites, observe plant foliage for the characteristic damage. Look on the undersides of leaves for mites. Pay close attention to field borders and weedy areas. Mites frequently get started and reach their highest density along field margins adjacent to roads where the plants are covered with dust. Apply treatments for mite control when mites become numerous and their damage appears excessive.

Broad Mite. Broad mites are minute arthropods with the female's body length being less than 1/64 inch, and the males about half the size of females. Adults are broadly oval and

Figure 22. Spider mite and spider mite eggs on a leaf.

Figure 23. Stippling of leaf caused by spider mite feedling.

whitish to yellow-green but appear translucent except under extreme magnification. Larvae and pupae appear similar to the adults. The appearance of the eggs is the key characteristic generally used to verify plant infestations by broad mites. Eggs are nearly transparent except for rows of whitish circular projections that give the egg a characteristic speckled appearance.

All stages of broad mite are found in terminal growth, with few if any mites found on leaves that have uncurled. Damage is caused by secretion of a plant growth regulator or toxin as the mites feed, and severe damage can occur at very low pest densities with symptoms on both foliage and fruit.

Foliar symptoms include leaf distortions, shortening of internodes, bronzing of leaves and terminal tissue and blistering, shriveling and curling of leaves. These symptoms can be easily confused with viral disease, micronutrient deficiency or herbicide injury. Infestations in pepper are frequently associated with a characteristic 'S' shaped twisting in the main vein in leaves. Fruit may be deformed, split or russeted. Damage may appear for weeks after the mites have been successfully controlled and, when combined with the difficulty in detecting the actual mites, makes evaluation of control measures difficult and has likely led to reports of control failures.

The mites' small size and ability to damage plants at very low densities generally results in plant injury serving as the first indication of an infestation. When damage is noted, examine terminals of symptomatic plants under magnification to verify the presence of broad mites. Similar sampling is necessary to evaluate control measures, as damage symptoms can continue to appear for two weeks after successful control. Damage will usually start in small clumps in the field and can spread rapidly. Broad mites are favored by warm, humid weather and are typically a greater problem during rainy periods in the late summer and early fall.

Sweet potato or Silverleaf Whitefly. The sweet potato whitefly, also called the silverleaf whitefly, is considered a minor pest of pepper, but its pest status may be changing. In Georgia, this pest is generally of little concern in crops grown in the spring, but populations can reach extraordinary levels under favorable conditions in the late summer and fall. This whitefly typically does not reproduce well on pepper and is of primary concern when high populations of adults move into very young pepper fields in the fall, when the adults' feeding can stunt growth. This pest situation may change in the future as scientists in Florida have reported increased reproduction of this pest on pepper.

Pod Feeders

European Corn Borer. European corn borer is an occasional, but difficult to control, insect pest of pepper. Fortunately spring plantings are less subject to infestations than late plantings of bell pepper. Pimento pepper has a long growing season and is more subject to heavy infestations.

Females lay eggs in groups of 15 to 35 on the undersides of pepper leaves. The overlapping scale-like eggs hatch in 5 to 7 days. Within 2 to 12 hours after hatching, the young larvae crawl to the calyx of pepper pods. Once under the calyx, they are protected from insecticides and natural enemies.

Young larvae bore through the walls of pepper pods and later feed on the seed core. This feeding causes small fruit to drop prematurely and larger fruit to eventually rot. When rotting begins, larvae usually leave the fruit to infest other fruit. Infested fruit are easily overlooked but can be detected by close examination of the calyx for signs of feeding, entry holes and frass (fecal debris). Larvae may, at times, bore into the stems and branches of pepper plants. Entrance holes are usually found at axils. As the borers tunnel within the stems and branches, fruit loss may result from limb breakage.

The number of European corn borer generations per year varies with latitude. In north Georgia, there may be as few as two generations whereas in south Georgia ,five to six generations may occur. The severity of damage is also variable but heaviest during dry years. Infestations of European corn borer can be detected by examining plants for presence of egg masses on the undersides of leaves.

Time insecticide treatments for control of European corn borers such that larvae are controlled before entering the fruits and stems. Treatments made after larvae have entered fruit and stems are of little value, so initiate sprays at the first sign of egg masses.

Pepper Maggot. The pepper maggot is the larval stage of a small fly. This is an occasional pest of peppers in Georgia. The natural food of this insect is horsenettle, but serious damage may occur on pepper. Heavy infestations of pepper maggots occur in fields when adult flies are attracted to rotting fruit caused by damage from other pests. They deposit eggs beneath the skin of peppers, and all larval development is completed inside where the larvae are protected from insecticides. For control of pepper maggots, begin treatments when flies are first seen in the field. Make repeat applications on a three- to four-day interval.

Pepper Weevil. Where the pepper weevil occurs, it is a key pest of pepper with the potential to cause severe yield losses. The adult weevil is a small gray to dark-colored beetle, with an arched body and a long stout snout, which is typical of weevils. The adult pepper weevil averages about ⅛ inch in length but varies considerably in size. The larva or grub is legless, resembling a small white grub.

The adult female weevil deposits eggs either in flower buds or in the fruit, and all immature stages develop within these protected environments. Females may lay 100 to 300 eggs over a one- to two-month period. There are several generations per season. The weevils have not been found to overwinter in commercial pepper fields in Georgia but are brought in on transplants from other areas.

The most important damage is the destruction of blossom buds and immature pods. The crop may be entirely lost if the infestation is severe and early. Infested pods turn yellow (or prematurely red in the case of pimiento peppers) and fall from the plant. Often they are malformed. In many cases the first detected sign of infestation is a few fallen pods, but by this time serious damage may be already done, and within the next 10 days a large part of the crop may fall. The feeding of grubs within the pods causes the seeds and cores to turn black. Pods attacked late in their development may appear to be sound but show this condition when opened.

Feeding punctures in the pods do not materially damage peppers intended for drying, but they appear as dark specks at the bottom of depressed areas and lower the quality of fruit

Figure 24. Adult pepper weevil.

Figure 25. Pepper weevil grub inside fruit.

used for fresh market or for canning. In the latter case, the punctures appear as black spots when the peppers are cooked.

Damage to blossom buds is similar to that done to pods. Larvae feed inside the bud and cause it to fall. However, unlike pods, feeding punctures by adults can also cause buds to drop.

Growers should only purchase transplants certified to be weevil free. Inspect plants from weevil infested areas closely, and growers should not accept any plants with fruiting structures. If transplants from an infested area are used, a preventive application prior to bud formation may be justified. During the growing season, cut open and examine fallen buds and small fruit for evidence of infestation. Begin treatments for pepper weevils when any fruit are found infested with adult or immature weevils. Once pepper weevil is established in a crop, scheduled insecticide applications are generally required as the immature stages are protected within the buds and pods and only the adult can be controlled.

Tomato Fruitworm (corn earworm). Among the most serious pests of peppers in the summer and fall is the tomato fruitworm or corn earworm. The larvae vary greatly in color from a light green to brown or nearly black and are lighter on the underside. They are marked with alternating light and dark stripes running lengthwise on the body. Early instar larvae have stout hairs which gives them a somewhat spiny appearance as compared to the smooth skin of most other caterpillars found on peppers.

Eggs are laid singly on the terminals of pepper plants. The eggs hatch in three to five days, and the larvae generally feed first on terminal foliage but can immediately attack buds and pods. The larva are rather restless and shift from one pod to another, so a single caterpillar may spoil several pods. This movement does benefit control efforts, as the caterpillars are exposed to insecticide applications as they move between fruit. Several generations of tomato fruitworm may develop each year. Apply treatments for tomato fruitworm control after bloom when 1 percent of fruit are infested with larvae or if eggs are easily found.

Beet Armyworm. Beet armyworm historically has been considered a secondary pest, with large populations usually occurring only after multiple applications of broad spectrum insecticides; however, in recent years, significant populations have been observed in the late summer and fall prior to heavy insecticide use.

Beet armyworms may feed on both the foliage and pods of pepper plants. Eggs are laid in masses on the undersides of foliage. Young larvae remain near the site of hatching, feeding in groups that cause characteristic foliar damage referred to has "hits." After feeding on foliage for a few days, medium-sized larvae (3rd instar) may migrate to the pods. They may tunnel into the pod under the calyx or eat directly through the pod wall. Because beet

Figure 26. Tomato fruitworm larva.

Figure 27. Early instar tomato fruitworm larva.


Figure 28. Beet armyworm larvae on leaf.

Figure 29. Beet armyworm egg mass hatching.

Figure 30. Southern green stink bug adult.


Figure 31. Nymph of the southern green stink bug.


Figure 32. Leaffooted bug adult.

armyworms start as foliage feeders, treatments can be delayed until hits are detected but should be applied prior to third instar. In practice, treatments are generally begun with first detection of egg masses or hits.

Other Armyworms. Both Southern armyworm and Yellowstriped armyworm are commonly encountered defoliators of pepper. Their behavior is similar to the beet armyworm, with eggs laid in masses, early instars feeding gregariously on foliage, and later instars feeding on foliage or fruit. The Southern armyworm is more prevalent than the Yellowstriped armyworm and can occur late in the spring. Larvae of both species have two lines of dark triangular marks on their backs and a longitudinal white to yellow line along each side. Yellowstriped armyworm seldom reach population densities that require treatment.

Tarnished Plant Bug. Tarnished plant bugs are sucking bugs that primarily attack young flower buds causing them to abort. Young flower buds turn yellow to black after tarnished plant bug feeding. Infestations may be heavy in spring plantings, and fruit set can be poor if the bugs are not controlled.

Both nymphs and adults feed on pepper. The nymphs are difficult to find unless high numbers are present. Scouting for the adults is relatively simple. Visually examine plants and treat if one adult per six plants is found.

Stink Bugs and Leaffooted Bugs. Several species of stink bugs can damage peppers. Stink bug adults are generally medium sized shield-shaped bugs with broad “shoulders” and a bluntly rounded abdomen. They also have a triangular shaped shield on their backs. The most common species in peppers are either a uniform green (Southern Green Stink Bug) or tan to brown with light colored underside (various species of Brown Stink Bugs). Stink bug nymphs are more oval shaped and vary greatly in color. Eggs are somewhat barrel-shaped and are deposited on end in tightly packed clusters.

Leaffooted bugs are brown, medium sized bugs that get their common name from the flattened leg segment of the hind leg, which gives this segment a leaf-like appearance. Stink bugs and leaffooted bugs have needle-like mouthparts with which they puncture plant tissue and remove sap. The greatest damage is caused by feeding on fruiting structures. Severity of the damage to fruit varies greatly with the development stage of the fruit. Damage early in fruit development can lead to severe deformities and abscission, while damage near harvest may result in small dark spots at the feeding site. These insects may also introduce bacteria and yeast as they feed, or they may simply provide a site of entry for disease organisms, resulting in fruit decay.

Weed Control

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Extension Agronomist — Weed Science

Effective weed management is one of many critical components of successful pepper production. Weeds compete with pepper for light, nutrients, water, and space as well as interfere with harvesting practices. Additionally, weeds can harbor deleterious insects and diseases. Severe weed infestations can reduce yield at least 50 percent even when pepper are produced on plasticulture if the weeds are left uncontrolled.

Weeds that usually cause problems in pepper are summer annual weeds including yellow and purple nutsedge, morningglory, purslane species, pigweed species and annual grasses.

One of the most effective tools for suppressing weeds in pepper is a healthy, vigorous crop. Good crop management practices that result in rapid pepper canopy development help minimize the effects of weeds.

Cultural Control Methods

Weeds can be controlled effectively through cultural practices that lead to rapid pepper canopy establishment,, thus providing an undesirable environment for weed growth. Cultural practices may include the following: 1) seeds or transplants free of weeds; 2) healthy and vigorous growing plants; 3) good seedbed preparation; 4) proper fertilization and watering; 5) follow recommended row spacing; and 6) management of diseases and insects.

Site selection also can play a significant role in weed management. Rotation away from fields infested with troublesome weeds, such as nutsedge, may minimize the presence of these weeds and allow the use of alternative crops and control methods. Additionally, so as to prevent weed spread from field to field during harvest, equipment and personnel should be cleaned when moving from heavily infested areas. This precaution can be of significant consequence in preventing or minimizing the introduction of new weeds species into “clean areas.”

Mechanical Control Methods

Mechanical control methods include field preparation by plowing or discing, cultivating, mowing, hoeing and hand pulling of weeds. Most of Georgia’s pepper are produced on mulch, thereby limiting the practicality of most mechanical control methods. Of course, hoeing and hand pulling of weeds is quite common. For those growers producing pepper on bare ground, mechanical control practices such as cultivation and primary tillage are very beneficial for managing weeds.

Mulching

The use of polyethylene mulch increases yield and earliness of vegetables. Mulches act as a barrier to the growth of many weeds. Nutsedge, however, is one weed that can and will penetrate through the mulch. Additionally, weeds that emerge in the transplant hole will greatly reduce yield and quality of the crop. Thus, fumigants and or herbicides are often used in conjunction with mulch.

Fumigants

Currently, methyl bromide is the fumigant of choice in pepper production because it is extremely effective in controlling diseases, nematodes and weeds, and most growers are comfortable applying this fumigant. Unfortunately, methyl bromide is being removed from the marketplace. The University of Georgia has been and continues to conduct many research trials to find a suitable alternative to methyl bromide. Contact your local Cooperative Extension office for up-to-date information on alternatives to methyl bromide. In general, fumigants are restricted use chemicals and must be handled carefully by a certified applicator. Apply all fumigants in full compliance with label recommendations and precautions.

Developing a Herbicide Program

Before selecting herbicides, growers should know what weeds are present or expected to appear, the soil characteristic (such as texture and organic matter content), the capabilities and limitations of the various herbicides, and how best to apply each herbicide.

Weed Mapping. The first step in a weed management program is to identify the problem; this task is best accomplished by weed mapping. Surveys should be developed each fall to provide written record of the species present and their population levels.

In-Season Monitoring. Monitor fields periodically to identify the need for postemergence herbicides. Even after herbicides are applied, continue monitoring to evaluate the success of the weed management program and to determine the need for additional control measures.

Proper weed identification is necessary since weed species respond differently to various herbicides. For assistance in identifying weeds contact your local county extension office.

Herbicides. Properly selected herbicides are effective tools for weed control. Herbicides may be classified several ways, depending on how they are applied and their mode of action in or on the plant. Generally, herbicides are either soil-applied or foliage applied. They may be selective or non-selective, and they may be either contact or translocated through the plant. For example, paraquat (Gramoxone) is a foliage applied, contact, non-selective herbicide, while metolachlor (Dual) usually is described as a soil-applied, translocated, selective herbicide.

Foliage-applied herbicides may be applied to leaves, stems and shoots of plants. Herbicides that kill only those parts of plants that the spray touches are contact herbicides. Those herbicides that are taken into the plant and moved throughout the plant are translocated herbicides. Paraquat (Gramoxone) is a contact herbicide while glyphosate (Roundup) or sethoxydim (Poast) are translocated herbicides.

For foliage-applied herbicides to be effective, they must enter the plant. Good coverage is critical, and these products often require the addition of some type of adjuvant. Soil-applied herbicides are applied either to the surface of the soil or incorporated into the soil. Lack of moisture or rainfall following application of soil-applied herbicides often results in poor weed control.

Many herbicides applied in Georgia offer residual weed control, which is beneficial in the crop where the herbicide was applied. Before applying any herbicide in a crop, however, you must review the herbicide label and obtain the needed information on rotation restrictions. Many herbicides applied in peanut, cotton, tobacco and vegetable crops can cause significant crop injury to pepper planted the following year.

For herbicide recommendations contact your local Cooperative Extension office or view the most recent *Georgia Pest Management Handbook.*

Stale Seedbed

Herbicide options in the pepper crop are extremely limited. The use of a stale seedbed approach prior to planting pepper on bare ground or prior to transplanting pepper into mulch can be extremely useful.

A stale seedbed approach allows the weeds to emerge; then they are treated with a non-selective herbicide (glyphosate or paraquat usually) prior to planting. Be extremely careful when applying herbicides overtop of mulch prior to planting; some herbicides cannot be successfully removed from mulch and may cause severe crop injury once the crop is planted. Both glyphosate and paraquat, however, can be applied over mulch as long as a rainfall or irrigation event of at least 0.5 inch occurs after applying these herbicides but before planting.

The author would like to thank Alan C. York (North Caroline State University) and Bill Stall (University of Florida) for their contributions to this publication.

Harvest, Handling and Sanitation

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Field Maturity

Pepper harvesting time is usually determined by the fruit color required for marketing. Bell (sweet) peppers for the fresh market should be harvested immature while fruits are firm, shiny in appearance, and have a fresh green calyx and stem. Irregular shape does not detract from edible quality, but it reduces eye appeal, which may lower market acceptability. Peppers having soft, pliable, thin flesh and pale green color (for certain varieties) are too immature for harvest.

Fruit injuries that penetrate the fleshy wall increase susceptibility to decay and should be eliminated or minimized. Decay may appear as water-soaked, bleached or blackened areas that may or may not be noticeably sunken into the pepper wall. Remove decayed fruit to prevent infection of other fruit on the plant.

As bell types mature on the plant, they tend to become sweeter and change from green to "chocolate" and then to red color. It is more difficult to find a market for sweet peppers at this stage of maturity, although some processors accept these fruits for color enhancement in processed foods. In recent years a premium fresh market for colored peppers has emerged, but consistent color is difficult to produce because the fruit must remain on the plant until the desired color has developed (Figure 33). It is very susceptible to damage from insects and diseases and to fruit cracking. Allowing peppers to color on the plant also inhibits the development of young fruit, thus reducing the yield for that crop planting.

Figure 33. Colored peppers bring premium prices.

Leave partially green or chocolate colored fruit on the plant until the next harvest when they will be fully red. Many attempts have been made to successfully ripen harvested green peppers using ethylene. Unlike the tomato, however, bell peppers cannot be ripened to a satisfactory red color if removed from the plant.

All peppers can be classified as having either "sweet" or "hot" (pungent) flesh. Bells are sweet while chile types are hot. Chile peppers are usually green when immature and turn red, yellow or orange at maturity, so harvest time depends upon market preference. Pungency (hotness) is caused by an oily substance called *capsaicin*, located in yellow sacks or pustules on the inside wall of the pepper pod. As long as these oil glands are not broken, a hot pepper will remain mild. Rough handling during harvest and packing, however, can increase a chile pepper's hotness.

Harvest

Bell peppers constitute the major fresh market pepper product and are harvested by hand in the field. Some small acreage growers use field packing, where sound peppers are packed into wire-bound crates or waxed corrugated boxes (Figure 34). Most pepper is hand harvested by field workers who place it into polyethylene picking buckets, then carry the

Figure 34. Field packing bell peppers.

filled buckets to flatbed trailers where the contents are dumped into open bulk bins (20 bushel) for transport to a centralized packinghouse.

Good harvesting management is essential to pack high quality peppers. Since pepper plants have brittle stems, care must be taken by the workers to remove fruit from the plant with stems attached. Peppers with intact stems are more resistant to bacterial soft rot than those with torn or partial stems. Discard on the ground any pepper showing signs of decay, and do not place it into the picking buckets; it can serve as a source of inoculum to infect otherwise healthy peppers.

Protect harvested peppers from direct sunlight while holding them in the field. Sun scald develops quickly on exposed peppers in loaded bulk bins. Park trucks loaded with these bins under shade if there is any delay (such as a noon meal break) in moving them to the packing shed. Field packed boxes of peppers should not be held on flatbed trailers in the heat after loading. A study of the effect of delayed cooling on field-packed peppers has shown that shelf life can be reduced by one-half if peppers are allowed to remain in full sunlight for 2 hours after harvest.

Clean and sanitize picking buckets at the end of each harvest day to prevent accumulated disease organisms from infecting sound peppers from the next production day. Rinse buckets with water to remove debris, then wash them in a sanitizing solution consisting of 5 ounces of 5.25 percent sodium hypochlorite (household bleach) mixed in 5 gallons of water. Do not harvest wet peppers because surface moisture increases field heat accumulation in the load and enhances disease development.

Physical damage occurs during bulk bin loading as peppers drop onto the hard wooden bottom (Figure 35). Many split as they strike the surface while others are bruised. Considerable pepper loss during field loading can be significantly reduced by simply padding the bottom of field bins.

Placement of foam padding in the bins reduced splitting and bruising, and resulted in a 40 percent decrease in product loss. Although used carpeting is available to most growers, its installation did not significantly reduce pepper damage during bin loading. Furthermore, carpeting would quickly become soiled and could then serve as a source of disease inoculum

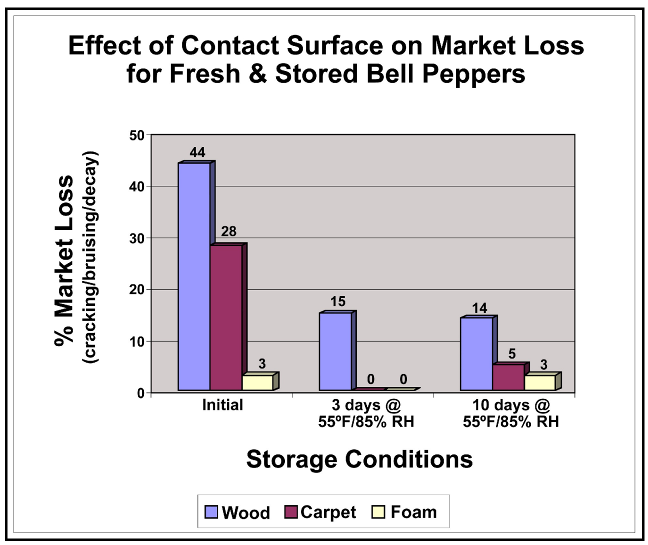

Figure 35. Graphic results of testing wood, carpet and foam padding in a harvest bin show that only 3% of 50 peppers dropped into a foam-padded bin showed signs of damage or decay after 10 days in storage. Each trial was conducted using 50 sound peppers over a 3-day harvest period, followed by cold storage at 55 degrees F and 85% humidity.

Figure 36. Padding along the conveyor minimizes damage to peppers when they are dumped from bins.

because it could not be properly cleaned and sanitized. Several equipment manufacturers now have foam padding of various thicknesses that is protected by a non-absorbent, smooth covering that is easily cleaned. This would make an ideal lining for field bins and would improve the quality and quantity of sound peppers harvested (Figure 36).

Postharvest Handling

The importance of postharvest handling cannot be overemphasized since approximately two-thirds of the total cost of pepper production is invested in harvesting, cooling and packaging. Bulk bins of harvested peppers are brought in from the field to a packing shed, dumped into a dry holding pit, conveyed beneath spray brush washers to remove field debris and then run beneath sponge dryers to remove excess water.

Fruit may or may not move through a waxer, depending on market preference. Waxing reduces shrinkage during storage and transit, and extends shelf life of fresh peppers. Peppers proceed down a grading line where fruit showing sun scald, stem punctures, bruises, disease or damage from stem rubs, hail or insects is removed. Peppers are then mechanically sized and packaged according to federal or industry standards.

In smaller operations, peppers are dipped into tanks of water or wiped with a soft cloth to remove dirt, sand, etc., from fruit surfaces. When peppers are washed, chlorine should be added to the wash water at the rate of 75 to 100 ppm free chlorine. Submerging peppers in dump tank water is not recommended because contaminated water may enter the fruit through the blossom end and contribute to storage rots. All fruit must be air dried before packaging to reduce storage rots.

Packing line operations can also damage peppers. Bruising and hairline cracking occur as peppers are dumped and conveyed along grading, sizing and packing belts. Shoulder bruising is the major type of damage (Figure 37). This leads to white blisters that form underneath the delicate skin. This discoloration often is not evident until peppers are packaged and stored. These weakened areas allow bacteria and fungi to enter the flesh and cause decay. Pinpointing and padding potential damage sites in a packing line with foam will lessen physical damage and improve shelf life of the pack-out.

Sanitation

Maintaining good sanitation throughout harvesting and handling peppers is extremely important. Human pathogens (those causing foodborne illness) can be transmitted by direct contact from infected employees or animals, or

Figure 37. Shoulder bruising is the result of rough handling in the field or at the packing shed.

through contaminated equipment and water. Once a vegetable is infected, pathogens are difficult or impossible to remove without some form of heat treatment (i.e., cooking, pasteurization). Of course, fresh peppers are normally consumed raw. Employees are the number one source of human pathogens, so training the field and packing house workers in proper hygiene techniques is critical.

Portable toilets equipped with handwash stations must be available, well stocked and used by all harvest crew members (Figure 38). Field containers (picking buckets, bins) and harvest aids (knives, gloves) must be cleaned and sanitized on a daily basis. Likewise, training, monitoring and enforcement of employees hygiene practices, such as proper hand washing after using the toilet, must be documented among packing shed employees to reduce the risk of human pathogen contamination to fresh peppers.

For many years packing sheds were not considered food handling businesses and, aside from sweeping floors to remove waste material and blowing debris off equipment with an air hose, sanitation was minimal to non-existent. Just one source of human pathogen introduction, however, at any point, can potentially contaminate all peppers passing through the line.

Figure 38. FDA regulations require that portable toilet and hand washing facilities be available within ½ mile of working field crews. [Photo courtesy of Trevor Suslow, UC-Davis.]

Packing shed sanitation should include the following:

- develop a Master Sanitation Schedule for cleaning all areas that do not come into contact with produce (i.e., drains, overhead structures, coolers, etc.) on a regular basis;
- write specific standard operating procedures (SOPs) for cleaning and sanitizing all product contact equipment and monitor to be sure the procedures are followed;
- implement a pest control and animal exclusion program.

Sanitize all water used for washing fresh produce in the field (field-packed) or a the packing shed, as well as water for hydrocooling or vacuum cooling produce. The most commonly used sanitizer is some form of chlorine. While research has shown that chlorinated water cannot sterilize fresh produce, the rationale for adding chlorine is to keep the number of human pathogens from concentrating in the water and cross-contaminating every piece of product that passes through it. Maintaining consistent and proper levels of chlorine in wash/cooling water is critical. Research has demonstrated that the concentration should be held between 75 and 150 ppm “free” chlorine, depending on the product and the organic load (matter floating or suspended in the water) at the time of use.

Chlorination can be accomplished by several methods: using a gas injection system, adding bleach (sodium hypochlorite), or dissolving calcium hypochlorite tablets. Monitor chlorination levels in the water frequently during operation with a free-chlorine test kit (Figure 39).

Since pH also has a drastic effect on chlorine’s ability to disinfect, maintain the pH of wash/cooling water between 6.0 and 7.5 to reduce the amount of chlorine needed to maintain the recommended free chlorine levels (Figure 40). Excessive use of chlorine, though, can cause “gassing off” (objectionable chlorine

Figure 39. Test kit for checking "free" chlorine in a solution.

Figure 40. Testing pH regularly will help maintain the maximum disinfectant activity of chlorine in wash or cooling water.

Figure 41. Barcoding facilitates trace-back and sanitizing of RPCs.

odor), can irritate workers' skin, is corrosive to equipment, and increases sanitation costs.

Both chlorine and pH measurements must be documented on a quality control form in order to comply with third party audits.

Grading and Packing

Federal grade standards for bell-type peppers include U.S. Fancy, U.S. No. 1 and U.S. No. 2. Most buyers will accept only the equivalent of U.S. No. 1 grade or higher. Tolerances for U.S. No. 1 grade state that peppers should have no more than 10 percent total defects (maturity, color, shape), including 5 percent serious damage (scarring, sunburn, insect damage), and 2 percent decay (soft rot) in any lot of peppers examined. Some buyers expect higher quality than these limits. Peppers must be graded to achieve uniform shape, color and size. Don't pack peppers showing red or chocolate color with fruit to be sold as green peppers.

Size is based on count per carton. Most buyers prefer large peppers (approximately 60 per carton) with a minimum of 2 inches in diameter and 2 inches in length. Pods should have four distinct lobes. Growers should check with their buyers to determine size preference. Chile peppers should be handled, graded and packed like bell types for fresh sale.

Since many types of shipping containers are used in marketing peppers, growers should check with their buyers to determine their preference. Peppers may be packed in wirebound crates, bushel baskets, and one and one-ninth bushel waxed corrugated cartons. In recent years major retailers such as WalMart, Kroger, etc., have requested growers to pack their produce in reusable plastic containers (RPCs) because containers offer more durability and versatility, can be properly sanitized, and contain bar codes for easy traceback purposes (Figure 41).

Containers must provide good ventilation with at least five percent of any container side being open so as not to restrict air movement through the container. Avoid packing in

Figure 42. An effective portable forced-air cooler for small operations can be constructed with plywood, a tarp and a squirrel-cage fan.

second-hand or used containers that are unacceptable to buyers. Shipping containers must not be under- or over-filled since this will result in short weights and physical damage to the peppers on stacking. Use eye appealing, reinforced containers, giving the name and address of the packer and having the size or weight of the product clearly marked on the package.

Cooling and Shipping

Peppers require fast cooling to prevent decay. While several methods could be used, "forced-air" cooling is recommended. Pepper cartons are placed in a specially designed refrigerated room and cold air is pulled rapidly through them using high pressure static fans. Once peppers are cooled to a storage temperature of 48 degrees to 50 degrees F, a solenoid switch turns off the fans and the room becomes a storage cooler. Forced-air cooling is more advantageous than room cooling because field heat is removed more rapidly from peppers, permitting longer shelf life.

For small acreage growers, forced-air cooling can be accomplished by using a squirrel-cage fan, a piece of plywood, and a canvas cover or tarpaulin to remove heat from small lots of peppers (Figure 42). A comparison of these two methods for boxed peppers shows that forced-air cooling requires only one-fifth the cooling time of room cooling. At the peak of the season when shipping schedules are short, peppers must often be adequately cooled in a matter of hours before loading onto a transport truck. Speed of cooling is critical and will affect pepper shelf life. Postharvest studies show a significant improvement in pepper shelf life when forced-air cooling is used instead of room cooling.

Forced-air coolers are slightly more expensive to build than conventional room coolers because of the fans and extra refrigeration capacity needed. Proper use of forced-air coolers, however, significantly enhances pepper quality and shelf life. Buyers pay higher prices for thoroughly cooled peppers.

Once pre-cooled, peppers must be held at 45-50 degrees F and 95 percent relative humidity for a two-week shelf life. Pre-cooling peppers before loading into transit trailers is critical. Truck coolers are not designed to remove field heat from peppers. They have only enough refrigeration capacity to maintain temperature once peppers are cooled. Peppers loaded in a transit trailer at 90 degrees F will likely arrive at the market at 90 degrees F. Buyers will not accept hot pepper loads.

Peppers are subject to chilling injury when held at temperatures below 45 degrees F. Chilling causes browning of the calyx-stem end and

Figure 43. Surface pitting indicates that peppers were stored at too cold a temperature.

will allow mold organisms to decay the calyx within four to five days. At 35 degrees F, peppers will develop surface pitting in a few days (Figure 43). Signs of chilling usually don't show up until peppers are moved to a higher temperature such as a display case in a retail market. Inspectors examine pepper loads for chilling disorders at terminal markets. Buyers won't accept chill-damaged peppers because they know it means reduced shelf life.

Peppers are very sensitive to ethylene, a ripening gas produced in excess by certain fruits and vegetables. Ethylene causes a bleaching of the green pigment, chlorophyll, in peppers and results in yellowish, chocolate and red colors. To prevent ethylene damage, don't store ripening tomatoes, cantaloupes, apples or peaches in the same room with peppers. Shipping "mixed loads" of peppers with ethylene producing commodities may cause quality problems. This damage can be minimized by ventilating the transit trailer before loading and placing the peppers at the back of the load where the air is coolest.

Marketing

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Extension Economist

Marketing pepper or any horticultural product is more than just selling. Marketing includes planning, production, harvesting, packaging, transportation, distribution, warehousing and pricing. To be successful, marketing must be responsive to consumers' demands. Simplistically, it must be customer oriented. To add to the multifaceted problems, marketing skills are required, and prior determination or knowledge of your targeted market is a necessary condition.

Is it direct marketing, or marketing to retail outlets, specialty food stores or wholesalers? Do you need any promotion? Is any specific harvest time required? Do consumers demand quality, freshness, "reasonable" prices or all of the above? All these and more questions need to be addressed.

Georgia Production and Farm Gate Value

The Georgia Agricultural Statistic Service (GASS) started collecting pepper data in 2000. Prior to that, most vegetable data was compiled by the University of Georgia Center for Agribusiness and Economic Development. The information in Figure 44 is a combination of both sources. Bell pepper is an important vegetable crop in Georgia. The farm gate value data was gathered from various issues of the Georgia Farm Gate Value Report, while the planted and harvested data was gathered from GASS. According to the Georgia Farm Gate Report, bell pepper ranked 24th in 2004 among all Georgia Commodity Ranking, as it generated slightly more than $60 million.

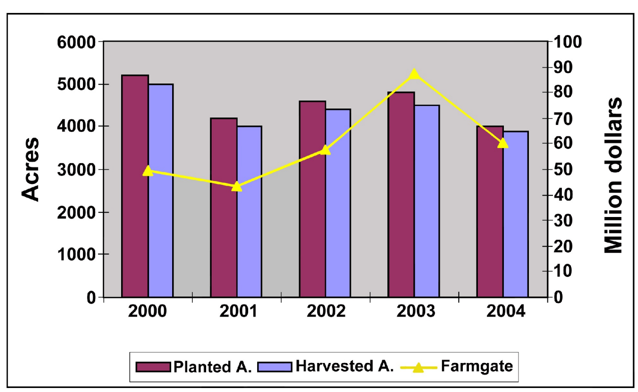

Figure 44. Georgia Bell Pepper Production and Farm Gate Value, 2000-2004.

The peak bell pepper farm gate value was recorded in 2003, when it generated more than $87 million and was ranked 18th in the state. Planted acreage peaked in 2000, when about 5,200 acres were planted, but only 5,000 were harvested. The trend in planted versus harvested acres has been fluctuating.

Wholesalers' and Distributors' Purchase Decision for Fresh Produce

A 2002 University of Georgia marketing survey asked wholesalers and distributors to rank their purchase decision for fresh produce. The result is summarized in Table 5. It is not surprising that quality is the most important factor in the wholesalers' and distributors' purchasing decision. It was interesting, however, that quality and price were ranked higher than reliability. Unfortunately, the origin of fresh produce was ranked last.

Wholesalers/distributors consider quality, price and reliability to be the most important factors in making a purchase. Being grown in Georgia will not help Georgia growers if their produce cannot compete on quality, price and reliability. These three factors are the minimal requirements needed to enter this market and can be thought of as a baseline from which grown-in-Georgia products must be differentiated.

A Georgia survey asked buyers to rank the factors that influenced their decisions to buy. Georgia pepper growers have benefitted from a growing market for peppers. Georgia's reputation for providing quality peppers in the quantity demanded has improved. Competition from other areas in the southeast requires that this reputation be maintained and improved. As production continues to expand, some growers will not be able to compete. Production skills alone will not ensure survival. Marketing will increase in its importance.

Table 5. Average Ranking of Wholesalers' and Distributors' Purchase Decision for Fresh Produce.

Importance of Specific Factors in Wholesalers'/Distributors' Purchase Decision for Fresh Produce - Ranked Most to Least Important (n=8)

Factor	Average Ranking
Quality	1.13
Price	2.00
Reliability	3.63
Quantity	4.13
Convenience	5.00
Transportation	5.25
Origin	6.88

Source: Wolfe, K and E.G Fonsah (2002) Wholesales and Distributors Outlook For Fruit and Vegetables Produced in Georgia, GFVGA News Vol. 7, No. 4, Fall.

Production, Domestic Consumption and Per Capita Use

U.S. production of fresh bell pepper has been continually on the rise since 1978 when only 520.1 million pounds were produced. By 2003, production had increased over three times to 1,680 million pound (Figure 45). According to Lucier and Plummer (2003), production rose at an increasing rate until 1996 when it reached its peak at 1,664 million

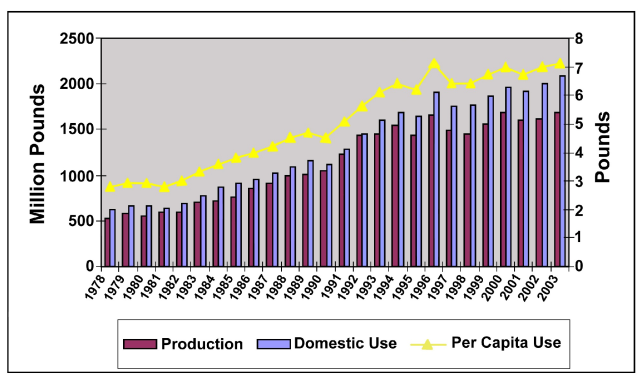

Figure 45. U.S. Fresh Bell Pepper Production, Domestic Consumption and Per Capita Use, 1978-2003. [Source: ERS/USDA Vegetables & Melon/VGS-2003/July 2003, p. 45]

pounds. Thereafter, it has been fluctuating. 2000 and 2003, however, were as good as the peak year, 1996, as 1,686 and 1,680 million pounds were produced, respectively (Figure 45).

Domestic consumption equally increased from 1978 to 2003 by nearly 3.5 times, while per capita use increased over 2.5-fold during the same time period. In 1978, domestic consumption stood at 616 million pounds compared to 2,083 million pounds in 2003. On the other hand, per capita use of pepper increased from 2.8 pounds in 1978 to 7.1 pounds in 2003 (Lucier and Plummer, 2003). In 2003, Georgia produced 1.35 billion pounds of pepper, whereas our total state consumption equaled 0.63 billion pounds, creating a surplus of 0.72 billion pounds that has to be sold in regional or foreign markets. If production continues to rise at the same pace, that would dampen prices.

Import, Export and Domestic Consumption

Despite the more than three-fold increase in production, the United States still imports a substantial amount of its pepper to supplement the ever increasing domestic demand. Production (Figure 45) plus import minus export = Domestic consumption (Figure 46). Although the United States also exports pepper, total quantity imported surpasses export, and this gap has widened since 1994. Pepper export was at its peak in 1992 when 189 million pounds were sold outside the United States. Thereafter, the export trend has been downward sloping.

In 2003, only 162 million pounds of pepper were shipped out of the United States. (Figure 46).

Domestic consumption has increased from 616 million pounds in 1978 to 2,083 million pounds in 2003 (Figure 46). To keep up with this tremendous rising pepper demand, import has become the talk of the day. In 1978, only 156 million pounds of pepper were imported to the United States compared to 565 million pounds in 2003, an increase of 262 percent. On the other hand, pepper export increased only 166 percent during the same time frame.

Production and Seasonal Pricing

Supply and demand determine the general price level of pepper. Seasonal average prices have been fluctuating. In 1978 the seasonal average price per cwt was $19.40 whereas in 2002 the price had jumped to $30.80 per cwt. The peak price was recorded in 1998 at $34.80 per cwt (Figure 47).

Pepper prices vary greatly within a season and between years. Most of the price variation within season is caused by weather effects on production. Price variations among years are

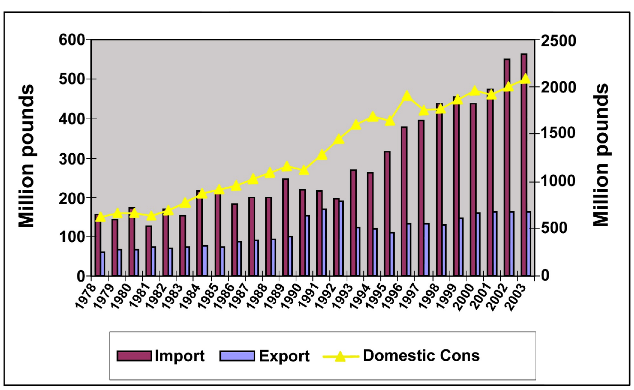

Figure 46. U.S. Pepper Import, Export and Domestic Consumption, 1978-2003. [Source: ERS/USDA Vegetables & Melon/VGS-2003/July 2003, p. 45.]

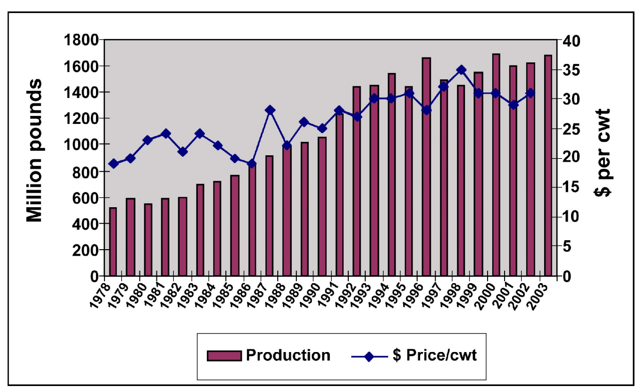

Figure 47. U.S. Pepper Production and Seasonal Prices, 1978-2003. [Source: ERS/USDA Vegetables & Melon/VGS-2003/July 2003, p. 45.]

caused by changes in acreage and weather. Little of the price variation is caused by demand changes. Demand changes are slight from year-to-year. Figure 47 further shows that despite the continuous increase in pepper production and supply overall price per cwt continues to rise. This trend actually violates economic theory.

For recent prices, visit the University of Georgia Extension Agricultural Economics Web site: www.agecon.uga.edu.

Consumers determine the demand by deciding what and how much they will buy. Thus marketing efforts must be consumer oriented. Consumers normally reflect their wants in the product and product characteristics they buy. Characteristics of pepper quality include shape, thickness, firmness and uniform glossy color.

Variety and age determine color. The most preferred color is dark green. Specialty markets may demand red, gold or other colors. Large peppers normally bring premium prices, regardless of color. The competing state's production levels determine the supply.

Conclusion

Georgia farmers have been successful in growing good quality pepper for the local, regional and foreign markets. Although there has been a tremendous growth in production and consumption of pepper for the past three decades, production in Georgia surpassed consumption, thus creating an excess. This excess production creates the need for new markets as the existing ones are either saturated or at the verge of saturation. It is therefore very important for any Georgian planning to produce pepper, or for the existing farmers who would like to expand their acreage, to first of all establish and guarantee a market before planting.

Despite the over three-fold increase in production nationwide and the climatic conditions, the United States still imports a substantial amount of its pepper to supplement the ever increasing domestic consumption. Domestic consumption has increased from 616 million pounds in 1978 to 2,083 million pounds in 2003. The continuous growth in production and consumption of pepper in and out of the United States has indeed increased the dollar value from about $400 million in 1978 to almost $500 million in 2002.

Due to NAFTA agreement, which has improved regional trade, pepper export value to Canada was worth $69.4 million, equivalent to 94.5 percent of total United States pepper export value, whereas $1.3 million was recorded for export to Mexico, equivalent to 1.8 percent in 2002.

Although the United States imported pepper from Mexico worth $122 million, $134.8 million, $188 million and $132.7 million in years 1999, 2000, 2001and 2002 respectively, bear in mind that Mexico also has comparative advantage in terms of weather, cheaper labor and other conditions over the United States.

Other countries that imported small amounts of pepper from the United States were Japan, the Netherlands, the United Kingdom, Taiwan and Germany. Increasing our shares in these markets would eliminate the existing excess production and might create room for expansion. The early adopters or entrants in these markets will make the most profit.

Most of the firms producing and supplying fresh bell and chili pepper, however, are U.S. companies based in Mexico and taking advantage of the cheaper labor and favorable weather conditions. In 1978, the seasonal average price was $19.40 whereas in 2002, the price had jumped to $30.80 per cwt. The peak price was recorded in 1998 at $34.80 per cwt.

Pepper prices vary greatly within a season and between years. Most of the price variation within season is caused by weather effects on production. Price variations among years are caused by changes in acreage and weather.

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Production Costs

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Pepper growers can use enterprise budgets to estimate production and break even costs. Budgets include cost estimates for those inputs necessary to achieve the specified yields over a period of years. Since production practices vary among growers, each grower should adapt budget estimates to reflect his or her individual situation. Detailed printed and computerized budgets are available in most county extension offices and on the University of Georgia Department of Agricultural and Applied Economics Web site: www.agecon.uga.edu

Farm Input Prices

Several factors can influence price of inputs, total cost of production and profit margin. Many farmers in Georgia need not invest in drip irrigation materials or dig a new well since they already have them available. If so, that would significantly increase profitability. Also motor sizes (HP) and cost for 6- or 8-inch wells are different depending on acreage. Quantity discounts for items such as packing supplies are factors that can affect price of inputs.

The cost estimate in this budget reflects a combination of the current agricultural practices in Georgia and recommendations from University of Georgia specialists. The prices were actual prices from vendors around the counties involved in pepper production, and they excluded quantity discounts. It is worth mentioning here, however, that a 3 percent tax should be added to the farm input prices.

Variable Cost of Producing Pepper

Total costs of producing any crop include both variable and fixed costs. The variable or operating costs vary with the adopted cultural practices. Common variable costs components include seed, fertilizer, chemicals, fuel, and labor. Pre-variable cost was $3,505.06 (Table 6 on page 55).

The cost of nematicide was $510.00, thus almost 14.6 percent of pre-variable cost. Other important cost components were plants ($654.30), fungicide ($173.76) and fumigation ($207.90) per acre. The cost of fumigation was separated from insecticide and herbicide because of the methyl bromide phase-out program, which will enable growers to use other alternative compounds. Variable costs are further broken down into pre-harvest and harvesting and marketing operations in the budget. This provides you an opportunity to analyze the costs at different stages of production.

Harvesting and Marketing Costs

Total harvesting and marketing cost was estimated at $4,615.00 per acre. This cost included picking and hauling, grading and packing, container and marketing. The calculation was based on an average yield of 1,300 boxes per acre (Table 7, page 55). Total variable or operation cost was $8,120.06, i.e., the sum of pre-harvest variable, harvesting and marketing costs respectively.

Fixed Costs of Producing Pepper

Fixed costs include items such as equipment ownership (depreciation, interest, insurance and taxes) management and general overhead costs. Most of these costs are incurred even if little production takes place, and you should consider these costs when planning production costs. Total fixed cost was $815.54. Irrigation, overhead and management costs were $233.51 and $525.76, respectively (Table 8, page 55).

Land cost may either be a variable or a fixed cost and varies significantly from county to county, from region to region, and whether it is irrigated or non-irrigated. Due to the differences, land cost was excluded. A fixed cost per hour of use shows ownership costs for tractors and equipment (depreciation, interest, taxes, insurance and shelter). Overhead and management are 15 percent of all pre harvest variable expenses. This amount pays for management and farm costs that cannot be allocated to any one specific enterprise. Overhead items include utilities, pick up trucks, farm shop and equipment, and fees (Table 8, page 55).

Table 6. Variable or Operating Costs of Producing Pepper.

Item	Unit	Qantity	Price	Amt/Acre
Variable Costs				
Plants	Thou	14.54	29.50	654.30
Lime, applied	Ton	1.00	26.00	26.00
Base fertilizer	Lbs.	12.00	9.50	114.00
Side-dressing fertilizer (soluble)	Gal.	60.00	7.75	465.00
Insecticide[1]	Acre	1.00	186.22	186.22
Fungicide	Acre	1.00	231.36	173.76
Nematicide	Acre	1.00	510.00	510.00
Herbicide	Acre	1.00	68.08	68.08
Plastic	Roll	2.80	68.50	191.80
Plastic removal	Acre	1.00	75.00	75.00
Drip tape	Ft.	8,700.00	0.02	174.00
Fumigation (1st crop)	Acre	150.00	1.39	207.90
Machinery	Hr.	5.00	21.00	105.00
Transplant labor	Hr.	20.00	7.00	140.00
Labor	Hr.	33.00	6.00	198.00
Land rent	Acre	1.00	0.00	0.00
Irrigation (machinery + labor)	Acre	1.00	65.08	65.08
Interest on operating capital	$	3,354.13	0.09	150.94
Pre-Harvest Variable Cost				3,505.06

[1]Fall plantings may require additional application, estimated at $30 or more.

Table 7. Harvesting and Marketing Costs of Producing Pepper.

Harvest and Marketing Costs				
Picking and hauling	Ctn.	1300	0.85	1,105.00
Grading and packing	Ctn.	1300	1.10	1,430.00
Container	Ctn.	1300	0.75	975.00
Marketing	Ctn.	1300	0.85	1,105.00
Total Harvest and Marketing Cost/Acre				4,615.00
Total Variable and Marketing Cost/Acre				8,120.06

Table 8. Fixed Costs of Producing Fresh Pepper.

Fixed Costs				
Machinery	Acre	1.00	56.27	56.27
Irrigation	Acre	1.00	233.51	233.51
Land	Acre	1.00	0.00	0.00
Overhead and management	$	3,360.22	0.15	525.76
Total Fixed Costs				815.54
Total Budgeted Cost per Acre				8,935.61

Cost/Unit of Production

The cost categories (Table 9) are broken down in cost per unit. The pre-harvest variable costs and the fixed costs decline with increases in yields. Pre-harvest variable cost per carton is $2.58 whereas harvesting and marketing cost per carton was $3.55. Fixed cost per carton was calculated at $0.61 and total budgeted cost per carton was $6.75. Given these scenarios, profitability will depend on the going market price per carton and cost of production.

Table 9. Costs per Carton of Producing Pepper.

Costs per Carton	
Pre-harvest variable cost per carton	2.58
Harvest and marketing cost per carton	3.55
Fixed costs per carton	0.61
Total Budgeted Cost per Carton	6.75

Budget Uses

In addition to estimating the total costs and break-even costs for producing peppers, there are other uses of the budget. Estimates of the cash costs (out of pocket expenses) provide information on how much money needs to be borrowed. The cash cost estimates are helpful in preparing cash flow statements. In the instance of share leases, the cost estimates by item can be used to more accurately determine a fair share arrangement by the landlord and tenant.

Risk Rated Net Returns

Since there is variation in yields and prices from year to year, an attempt is made to estimate the “riskiness” of producing peppers. The Extension Agricultural Economics Department uses five different yields and prices to calculate risk. The **median** values are those prices and yields a particular grower would anticipate to exceed half the time (Table 10).

Half the time, he or she would anticipate not reaching below these prices and yields. **Optimistic** values are those prices and yields a grower would expect to reach or exceed in one-year-in-six. The **pessimistic** values are poor prices and yields that would be expected one-year-in-six. The **best** and **worst** values are those extreme levels that would occur “once in a lifetime” (1 in 49).

The risk rated section (Table 11) shows there is a 95 percent chance of covering all costs and obtaining a base budgeted net revenue of $4,064. Fifty-one percent of the time a grower would expect to net $4,012 or more. Forty-nine percent of the time he/she would expect to net less than $4,012. One year out of six he would expect to make more than $7,565 per acre or less than $312.

Table 10. Risk Rated Return for Pepper Yield and Prices

	Best	Opt	Median	Pess	Worst
Yield (cartons)	1,900	1,600	1,300	1,000	700
Price per carton	12.00	11.00	10.00	9.00	7.00

Table 11. Risk Rated Returns over Total Costs Net Return Levels (top row); the chances of obtaining this level or more (middle row); and the chances of obtaining this level or less (bottom row).

	Best	Opt	Expected	Pess	Worst
Returns ($)	7,565	6,381	4,012	1,545	312
Chances	6%	32%	51%		
Chances			49%	16%	7%
Chances for Profit		95%	Base Budgeted Net Revenue		4,064

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